MOFFAT
COLLECTION SYSTEM PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT

Chapter 4:
Total Environmental Effects

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4.0 INTRODUCTION

This chapter describes the potential cumulative effects that would result from the Moffat Collection System Project in combination with other reasonably foreseeable future actions (RFFAs). Therefore, this section presents the total environmental effects that are anticipated to occur by 2032. The regulations for implementing the National Environmental Policy Act of 1969, as amended, define cumulative impacts as “the impact on the environment which results from the incremental impact of the action when added to other past, present, with RFFAs and regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time” (40 Code of Federal Regulations [CFR] 1508.7). This regulation refers only to the cumulative impact of direct and indirect effects of the Proposed Action and its alternatives when added to the aggregate effects of past, present, with RFFAs.

The U.S. Army Corps of Engineers’ Section 404(b)(1) Guidelines state that “cumulative impacts are the changes in an aquatic ecosystem that are attributable to the collective effect of a number of individual discharges of dredged or fill material. Although the impact of a particular discharge may constitute a minor change in itself, the cumulative effect of numerous such piecemeal changes can result in a major impairment of the water resources and interfere with the productivity and water quality of existing aquatic ecosystems” (40 CFR 230.11[g][1]).

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4.1 METHODOLOGY FOR TOTAL ENVIRONMENTAL EFFECTS ANALYSIS

The total environmental effects analysis for the Moffat Collection System Project (Moffat Project or Project) evaluates past, present, and cumulative actions that continue to influence existing environmental conditions. The total environmental effects analysis also includes reasonably foreseeable future actions (RFFAs) taken by other entities (Federal or non-Federal) and the Board of Water Commissioners' (Denver Water's) existing operations that, when combined with one of the Project alternatives, may result in a cumulative effect on the environment. For purposes of organization of this Environmental Impact Statement (EIS), cumulative effects are evaluated in two timeframes: (1) past or ongoing present actions, and (2) future actions. Next, a discussion of climate change issues and future actions not considered reasonably foreseeable are presented. Finally, cumulative effects of the alternatives on all resources are discussed.

Past/Ongoing Present Actions

Past or ongoing actions were included in the total environmental effects analysis if they met the following two criteria:

1. Similar water- or land-based actions have occurred within the same geographic boundaries where effects from the Moffat Project alternatives are expected to occur. Figure 2-1 shows the geographic area surrounding the location of the alternative components; Figures 3.0-1, 3.0-2, 3.0-3, and 3.0-4 display the locations of the river segments potentially affected by stream flow alterations.
2. A past or current action, the incremental impact of which, when evaluated in addition to a Moffat Project alternative, might have cumulative effects.

Future Actions

Potential future actions were considered reasonably foreseeable and included in the total environmental effects analysis if they met all of the following criteria:

1. The action would occur within the same geographic area where effects from the Moffat Project alternatives are expected to occur. Geographic extent was chosen based on boundaries of similar land- and water-based projects where the direct and indirect effects of the Moffat Project alternatives could be adequately and reasonably quantified (using Platte and Colorado Simulation Model [PACSM]) or qualified.
2. The action would affect the same environmental resources as the Moffat Project alternatives, and contribute to the total resource impact.
3. There is reasonable certainty as to the likelihood of the action occurring within the same projected time period as construction and initial operation of the Moffat Project (by 2032), regardless of the implementation of any of the Moffat Project alternatives, including the No Action Alternative. This time period was chosen because it coincides with Denver Water's demand/supply planning objectives, strategy, and milestones.

Land- and Water-based Projects and Geographic Boundaries

Total environmental effects analyses were conducted for past, present, and reasonably foreseeable future land- and water-based actions. Geographically, cumulative effects resulting from water-based actions are likely to occur on both the East and West slopes of Colorado, thus, cumulative effects are evaluated within the local operational and socio-political boundaries of these activities. The effects of land-based actions are limited to the Front Range (East Slope) since no Project-related ground disturbing activities would occur on the West Slope. Land-based actions were identified by reviewing various city and county comprehensive plans, recreation management plans, proposed transportation improvement project plans, regional population statistics, and land parcel database searches.

PACSM Boundaries and Stream Flow Effects

Pertinent cumulative effect timeframes and/or hydrologic scenarios were evaluated using PACSM. The following time frames were compared to analyze the total environmental effects expected to occur as a result of implementing each Project alternative in combination with other RFFAs.

Approach for Evaluating the Proposed Action with the Environmental Pool for Mitigation

Under the Proposed Action with RFFAs, a 77,000 acre-feet (AF) enlargement would be constructed at Gross Reservoir. Of the 77,000 AF enlargement, 72,000 AF would be utilized to provide new firm yield to Denver Water's system and 5,000 AF would be an Environmental Pool for mitigation. The estimated ground disturbance for the Proposed Action conservatively assumed the proposed inundation area (i.e., the area between elevation 7,282 and 7,400 feet), plus 10 feet above the expanded reservoir pool to account for potential tree removal and other construction-related activities. The additional area of inundation associated with the Environmental Pool (i.e., the area between elevation 7,400 and 7,406 feet) is within this impact area. Thus, the impact analysis of ground-disturbance associated with the Proposed Action with or without the Environmental Pool is the same. The environmental effects discussed for surface water correspond with the 72,000 AF enlargement whereas the operations and effects associated with the 5,000 AF Environmental Pool are discussed in Appendices H-22 and M-2, and were independently evaluated by the U.S. Army Corps of Engineers (Corps). Additional analyses conducted by the Corps for recreation and aquatic biological resources associated with the Environmental Pool are also presented in Appendices H-22 and M. The environmental effects of a 77,000 AF expansion are expected to be similar to the 72,000 AF expansion.

Comparison of Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032)

- **Current Conditions (2006)** reflects the Denver Water-related current administration of the Colorado and South Platte river basins, demands, infrastructure, and operations. Under the Current Conditions (2006) scenario, Denver Water's existing average annual demand is 285,000 AF/yr.

- **Full Use with a Project Alternative with RFFAs (2032)** reflects conditions in Denver Water's system when the Moffat Project is completed and in full use in 2032. This scenario reflects each action alternative in combination with other RFFAs. Under this scenario, Denver Water's average annual demand is 363,000 AF/yr (379,000 AF/yr demand less the 16,000 AF/yr demand met by conservation measures) and the Moffat Project with RFFAs would be providing 18,000 AF/yr of new firm yield.

The following graphic represents the timelines by which total environmental effects were evaluated.

The cumulative effects scenario (2032 with Project) was used to bound the identification of potential cumulative effects related to potential stream flow changes. Cumulative effects analysis includes RFFAs, plus other entities that have implemented projects/actions. The potential hydrologic effects of implementing a Moffat Project alternative, with the cumulative effect of other entities' RFFAs, are based on this scenario. PACSM includes the proposed water-related projects that are reasonably foreseeable between Current Conditions (2006) and Full Use with a Project Alternative (2032) (refer to Section 4.3). Additional RFFAs that are not incorporated in PACSM were addressed qualitatively (refer to Section 4.3). Hydrologic effects that are attributable to the Moffat Project alternatives are discussed in Chapter 5.

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4.2 PAST ACTIONS

The identification of the effects of past actions is critical to understanding the environmental condition of an area. Knowing whether a resource is healthy, declining, near collapse, or not functioning is necessary for determining the significance of any added impacts due to the Moffat Collection System Project (Moffat Project or Project).

Recent guidance on the consideration of past actions in cumulative effects analysis states that "…it is not practical to analyze how the cumulative effects of an action interact with the universe; the analysis of environmental effects must focus on the aggregate effects of past, present and reasonably foreseeable future actions (RFFAs) that are truly meaningful" (CEQ 2005). This Environmental Impact Statement considers actions that have occurred in the past and have resulted in cumulative effects that continue to influence the present environmental conditions with RFFAs in the Project area.

4.2.1 Past Water-based Actions

Water Supply Reservoirs

There are numerous existing reservoirs that are currently affected by operations of the Board of Water Commissioners' (Denver Water's) North and South systems, and which would experience some degree of cumulative effects with Project implementation. The operations of these reservoirs are described primarily in Sections 3.1 and 5.1. These ongoing reservoir operations and the effect they have on reservoir contents and levels, and the existing effects on stream flow, are incorporated into the Platte and Colorado Simulation Model (PACSM) that was done to support the analysis of Project impacts. Existing reservoirs in the Project area include Gross, Dillon, Williams Fork, Wolford Mountain, Antero, Eleven Mile Canyon, Cheesman, Strontia Springs, Ralston, and Chatfield reservoirs. Gross, Dillon, and Williams Fork reservoirs would experience the greatest changes with the Moffat Project.

Trans-basin Diversions

A trans-basin water diversion occurs when water is exported from one watershed to another, typically from a West Slope watershed to the East Slope (Colorado Foundation for Water Education 2003). The first trans-basin diversion project to divert water out of the Colorado River Basin began in the 1880s with the construction of the Grand River Ditch by the Water Supply and Storage Company. Grand Ditch diverts water across the Continental Divide at La Poudre Pass to farmers and ranchers on the East Slope. The City of Thornton also is a 50 percent (%) shareholder in the Grand River Ditch (Coley/Forrest, Inc. 2007).

The Moffat Tunnel was the pilot bore for the Moffat Railroad Tunnel and was completed in 1927. The pilot bore was enlarged and partially lined in 1935 and 1936. The first diversion of water occurred in 1936. Denver Water purchased additional water rights in Grand County in the mid-1950s. Between 1935 and mid-1950, Denver Water constructed a series of diversion canals and tunnels from approximately 31 creeks and rivers to divert water to the Moffat Tunnel. The Roberts Tunnel was constructed from 1946 through the early

1960s and water began flowing through it to the South Platte River in 1964 (Coley/Forrest Inc. 2007).

The U.S. Department of Interior, Bureau of Reclamation constructed the Colorado-Big Thompson (C-BT) Project in the 1930s, which they jointly operate with Northern Colorado Water Conservancy District (NCWCD). The C-BT Project consists of 14 storage dams and 10 reservoirs, including Granby Reservoir, Shadow Mountain Reservoir, Grand Lake, and the Alva Adams Tunnel. The NCWCD Municipal Subdistrict owns and operates the Windy Gap Project, completed in 1985, which diverts water from the Colorado River downstream of the confluence of the Colorado and Fraser rivers to Granby Reservoir.

South Platte River

The South Platte River has undergone extensive development for agricultural irrigation, power generation, and municipal water uses. Water supply development in the South Platte River Basin began in the mid-1880s in response to increasing agricultural water needs. Water was typically diverted through canals to farm fields. Trans-basin diversions were also initiated in an effort to meet water supply needs. Major trans-basin diversions into the South Platte River Basin include the previously described C-BT Project, Windy Gap Project, Moffat Tunnel Collection System, and the Roberts Tunnel Collection System. The South Platte River currently contains 15 major dams and reservoirs to supply water for agricultural, industrial, and municipal uses (DOI 2006; CWCB 2004).

4.2.2 Past Land-based Actions

Population Growth and Development along the Front Range

The Denver Metropolitan area growth rate has consistently outpaced the national rate every decade since the 1930s. The region grew steadily during the past decade, averaging 1.5% population growth each year from 2000 to 2010. By 2030, the Denver Metropolitan area population is anticipated to increase by nearly 30% to almost 3.7 million. Currently, the Denver Metropolitan area population is approximately 2.9 million (refer to Table 4.2.2-1). Past and ongoing development along the Front Range has created a demand for resources, including water.

Table 4.2.2-1
Denver Metropolitan Area Population Statistics

Year	County							Denver Metropolitan Area Total
	Adams	Arapahoe	Boulder	Broomfield	Denver	Douglas	Jefferson	
2035 Proj	693,941	820,431	380,823	84,995	779,773	481,772	623,736	**3,865,471**
2030 Proj	645,884	774,353	366,960	82,049	749,555	450,846	612,885	**3,682,532**
2025 Proj	597,787	725,282	350,481	77,432	719,676	415,872	593,742	**3,480,273**
2020 Proj	544,258	673,230	332,107	71,211	686,613	373,308	571,753	**3,252,481**
2015 Proj	491,263	619,762	312,668	63,926	645,364	322,985	548,447	**3,004,415**
2012 Proj	460,846	590,675	300,823	58,999	622,148	297,485	539,973	**2,870,948**
2010	441,603	572,003	294,567	55,889	600,158	285,465	534,543	**2,784,228**
2000	363,857	487,967	291,288	---	554,636	175,766	525,507	**2,400,570**
1990	265,038	391,511	225,339	---	467,610	60,391	438,430	**1,848,319**
1980	245,944	293,621	189,625	---	492,365	25,153	371,753	**1,618,461**
1970	185,789	162,142	131,889	---	514,678	8,407	233,031	**1,235,936**
1960	120,296	113,426	74,254	---	493,887	4,816	127,520	**934,199**
1950	40,234	52,125	48,296	---	415,786	3,507	55,687	**615,635**
1940	22,481	32,150	37,438	---	322,412	3,496	30,725	**448,702**
1930	20,245	22,647	32,456	---	287,861	3,498	21,810	**388,517**
1920	14,430	13,766	31,861	---	256,491	3,517	14,400	**334,465**
1910	8,892	10,263	30,330	---	213,381	3,192	14,231	**280,289**
1900	---	153,017	21,544	---	---	3,120	9,306	**186,987**

Source: Colorado Department of Local Affairs, State Demography Office.
Notes:
--- = not available
Proj = projected population growth

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4.3 REASONABLY FORESEEABLE FUTURE ACTIONS

4.3.1 Future Water-based Actions

Several water-based actions on the East and West slopes were considered in the evaluation of cumulative hydrologic effects, as shown in Table 4.3.1-1. Water-based actions refer to proposed water storage and diversion, water rights changes, and Section 404 activities on Colorado's East and West slopes. Several of these actions are anticipated to be on line by the time the Board of Water Commissioners' (Denver Water's) projected demands are estimated to begin to exceed system supplies. Thus, these projects were incorporated in the Platte and Colorado Simulation Model (PACSM) in the Full Use of the Existing System, No Action Alternative (2032 without Project), and Moffat Collection System Project (Moffat Project or Project) alternative (2032 with Full Use of the Existing System) scenarios. Those projects included in the PACSM (output displayed in Appendix H) were included in the model as they are anticipated to be brought on line. Projects that were not included in PACSM are addressed qualitatively in the following sections. East Slope and West Slope projects are discussed separately.

Table 4.3.1-1
Water-based Actions Considered for Cumulative Effects Analysis

Water-based Action	Included in PACSM	Addressed Qualitatively
REASONABLY FORESEEABLE WATER-BASED ACTIONS		
East Slope Projects		
1) Halligan-Seaman Water Supply Project		✓ Downstream of Henderson gage
2) Northern Integrated Supply Project	Partially	
3) Denver Water Reuse Project	✓	
4) Aurora Prairie Waters Project	✓	
5) Rueter-Hess Reservoir (16,200 AF and enlarged 72,000 AF reservoir)		✓
6) Dry Creek Reservoir Project		✓ Downstream of Henderson gage
7) Chatfield Reservoir Storage Reallocation Project		✓
8) Augmentation of Lower South Platte Wells		✓ Downstream of Henderson gage
9) East Cherry Creek Valley Project		✓ Downstream of Henderson gage
10) Cache la Poudre Flood Reduction and Ecosystem Restoration Project		✓ Downstream of Henderson gage
11) Water Infrastructure and Supply Efficiency (WISE)		✓
West Slope Projects		
12) Windy Gap Firming Project (WGFP)	✓	
13) Urban Growth in Grand and Summit Counties	✓	
14) Reduction of Xcel Energy's Shoshone Power Plant Call		✓

Table 4.3.1-1 (continued)
Water-based Actions Considered for Cumulative Effects Analysis

Water-based Action	Included in PACSM	Addressed Qualitatively
15) Changes in Releases from Williams Fork and Wolford Mountain Reservoirs to Meet USFWS Flow Recommendations for Endangered Fish in the 15-Mile Reach	✓	
16) Wolford Mountain Reservoir Contract Demand	✓	
17) Expiration of Denver Water's Contract with Big Lake Ditch in 2013	✓	
18) Colorado Springs Utilities' Substitution and Power Interference Agreements at Green Mountain Reservoir	✓	
19) 10,825 Water Supply Alternatives		✓
20) Colorado River Cooperative Agreement		✓
21) Fish and Wildlife Enhancement Plan		✓
WATER-BASED ACTIONS CONSIDERED NOT REASONABLY FORESEEABLE FUTURE ACTIONS		
22) Parker Water and Sanitation District Transfer of Agricultural Water Rights		
23) Regional Watershed Supply Project		
24) Yampa Pumpback Project		
25) Colorado River Return Project		
26) Blue River Pumpback with Wolcott Reservoir		

Notes:
AF = acre-feet
PACSM = Platte and Colorado Simulation Model
USFWS = U.S. Fish and Wildlife Service

East Slope Projects

Halligan-Seaman Water Supply Project

The Halligan-Seaman Water Supply Project includes the proposed expansion of the existing Halligan Reservoir and Milton Seaman Reservoir. Both of these facilities are located on the North Fork Cache la Poudre River. The project is in the initial stages of the National Environmental Policy Act of 1969, as amended, process. As a result, the alternatives are not yet well defined. Preliminary information on the facilities and operations of Halligan Reservoir enlargement was based on a letter, dated October 25, 2006, from Nancy Koch (City of Greeley) and Clifford Hoelscher (City of Fort Collins) to Chandler Peter (U.S. Army Corps of Engineers [Corps]). This is an ongoing Corps-led Environmental Impact Statement (EIS) and the following description of the project has not changed since the publication of the Moffat Draft EIS in 2009. The Corps is continuing to work with the applicants to develop and screen alternatives and model potential operations.

The applicants in the Halligan Reservoir enlargement project include the City of Fort Collins and the North Poudre Irrigation Company (NPIC). Based on preliminary information available for this project, the anticipated size of the Halligan Reservoir enlargement is 13,150 acre-feet (AF) (8,150 AF for Fort Collins and 5,000 AF for NPIC). The anticipated sources of water to be stored in the enlargement would consist primarily of converted agricultural water rights and, to a lesser extent, water available from the Halligan Reservoir conditional storage decree and some portion of the ⅛ interest in the Grey Mountain Reservoir conditional decree. The agricultural rights could consist of rights from several different irrigation ditches in the Cache la Poudre River Basin. The applicants do not yet know at this time the exact mix of agricultural rights that would be used.

It is anticipated that the City of Fort Collins would make relatively small releases from Halligan Reservoir in the winter months to help meet water demands and return flow obligations associated with converted agricultural water rights. Additional releases would be made in drought years. NPIC would likely operate its portion of the Halligan enlargement on an as-needed basis. Releases from their portion of Halligan Reservoir would most likely occur in dry years and during the latter part of the summer.

The City of Greeley is the proponent of the Seaman Reservoir expansion. Based on preliminary information available for this project, the anticipated size of the Seaman Reservoir enlargement is 48,000 AF. The anticipated sources of water to be stored in the enlargement would consist primarily of converted agricultural water rights, some portion of the ⅛ interest in the Grey Mountain Reservoir conditional decree, and water available from the Seaman Reservoir and Rockwell Ranch conditional storage decrees. The City of Greeley does not yet know the exact mix of agricultural rights but the rights would draw water from the Cache la Poudre and Laramie river basins.

Greeley anticipates that it would make consistent releases from Seaman Reservoir in the winter months. Winter releases would likely be delivered to the Greeley Filters Pipeline and treated at the Bellvue treatment plant. Additional releases from Seaman Reservoir would likely be made in drought years when the yield of Greeley's other water supplies is limited. The magnitude of releases has not yet been determined.

Applicants of the Halligan-Seaman Water Supply Project have modeled potential operations due to the development of the Common Technical Platform that is being used for this project and Northern Integrated Supply Project (NISP). PACSM was not modified to reflect the Halligan and Seaman Reservoir enlargements project due to the limited amount of public information available.

Northern Integrated Supply Project (Glade Reservoir and the South Platte Water Conservation Project [SPWCP])

NISP is anticipated to provide project participants with a firm yield of approximately 40,000 acre-feet per year (AF/yr) through a regional project. The Applicant's preferred alternative includes a proposed Glade Reservoir with an active storage capacity of approximately 170,000 AF. Associated with Glade Reservoir would be a forebay, pump station, and improvements to the Poudre Valley Canal to deliver water from the Cache la Poudre River to Glade Reservoir. NISP proposes to use Northern Colorado Water Conservancy District's (NCWCD's) ⅞ interest in the Grey Mountain Reservoir junior conditional storage rights as a source of project yield. The other major component of the Applicant's preferred alternative is the SPWCP. The main feature of the SPWCP is the proposed Galeton Reservoir with an active storage capacity of approximately 45,624 AF.

Associated with Galeton Reservoir would be a forebay, pump station, and pipeline to deliver water diverted from the South Platte River downstream of the confluence with the Cache la Poudre River to Galeton Reservoir or directly to the Larimer Weld and New Cache canals. The SPWCP would be operated to exchange water stored in Galeton Reservoir to the New Cache Canal and Larimer Weld Canal as a source of substitution for an exchange of water historically diverted by the irrigation companies. NISP would also substitute Galeton Reservoir and/or South Platte River water in exchange for water in the existing Terry Lake, Big Windsor, and Timnath reservoirs. NISP proposes to divert water from the South Platte River using NCWCD's conditional water rights for the SPWCP. In 2008, the Corps issued a Draft EIS for NISP. Due to the number and complexity of significant comments received, the Corps is currently preparing a Supplemental Draft EIS. If permitted, construction of the project would likely begin in 2020.

The NISP alternatives were simulated using a series of integrated hydrologic models known as the Common Technical Platform model sequence. Model data were relied on to analyze the effects of both Glade and Galeton reservoirs. Modeled flows were evaluated for the Cache la Poudre River at the confluence with the South Platte River and flows at the Kersey gage on the South Platte River downstream of the Cache la Poudre River confluence. Cache la Poudre flows at the confluence with the South Platte River were incorporated in PACSM because Glade Reservoir was anticipated to be on line before the Moffat Project is operational. The effects of the SPWCP on South Platte River flows were not included in PACSM because that project is anticipated to be on line after Denver Water's projected demands are estimated to begin to exceed system supplies (Full Use of the Existing System). The cumulative effect of NISP is to decrease South Platte River flows downstream of the confluence of the Cache la Poudre River due to the proposed project's reliance on the development of existing and/or new conditional water rights for diversion and exchange of native river water. Table 4.3.1-2 summarizes average, wet, and dry year baseline and project flows for NISP for the South Platte River at Kersey. This location is below the diversion point for the proposed SPWCP, and therefore reflects the full impact of all NISP diversions upstream.

Baseline flows in Table 4.3.1-2 reflect existing upper South Platte hydrology. The baseline condition represents the 2005 level of urbanization in the Denver Metropolitan and North Front Range areas; the 2005 distribution of the C-BT Project use; and trans-mountain reuse consistent with historical levels (approximately 10 percent [%]). This is assumed to represent South Platte River flow conditions at the present time (Gibbens 2006; Pineda et al. 2003). For the project scenario with Glade and Galeton reservoirs on line, hydrology for the upper South Platte River model input reflects 2005 levels of urbanization; the 2005 C-BT distribution; and 100% trans-mountain reuse planned through Denver Water's Reuse Project and Aurora's Prairie Waters Project (PWP). In addition, the project scenario includes a 5% safety factor on the NISP demand, raising it to 42,000 AF rather than the project participants' actual demand of 40,000 AF (Gibbens 2006; Pineda et al. 2003).

Table 4.3.1-2
Summary of Average, Wet, and Dry Year Flows (cfs) at the South Platte River at Kersey Gage for NISP (Glade Reservoir Plus South Platte Water Conservation Project)

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Baseline Flows												
Wet Year	816	743	785	891	848	1,253	3,071	4,802	1,072	899	906	1,127
Average Year	900	720	750	866	910	918	1,644	1,872	619	396	579	722
Dry Year	673	613	653	840	868	653	712	637	204	235	363	441
Project Flows												
Wet Year	745	695	731	841	824	1,242	2,957	4,222	1,018	871	839	1,101
Average Year	859	678	670	803	881	898	1,505	1,594	595	389	536	692
Dry Year	617	566	586	787	825	643	664	604	199	237	344	431
Change in Flows												
Wet Year	-71	-48	-54	-49	-24	-11	-114	-580	-54	-29	-68	-26
Average Year	-41	-41	-80	-63	-30	-20	-139	-278	-23	-8	-44	-31
Dry Year	-56	-47	-67	-53	-43	-10	-48	-33	-5	2	-19	-10
Percent Differences												
Wet Year	-8.7%	-6.5%	-6.9%	-5.5%	-2.9%	-0.9%	-3.7%	-12.1%	-5.1%	-3.2%	-7.5%	-2.3%
Average Year	-4.5%	-5.8%	-10.7%	-7.3%	-3.3%	-2.1%	-8.4%	-14.9%	-3.8%	-1.9%	7.5%	-4.2%
Dry Year	-8.3%	-7.7%	-10.3%	-6.3%	-5.0%	-1.5%	-6.8%	-5.2%	-2.5%	0.8%	-5.1%	-2.3%

Notes:
Data provided by HDR based on Poudre Basin MODSIM model runs for the NISP EIS.
cfs = cubic feet per second
NISP = Northern Integrated Supply Project

As shown in Table 4.3.1-2, decreases in South Platte River flows would be greatest during runoff in May and June in average and wet years. This is the result of NISP's junior water rights coming into priority and making significant diversions in wet years. Decreases in flow are considerably less in dry years. The maximum monthly average decrease in flows would occur in June, with a 278 cubic feet per second (cfs) or 15% decrease. In wet years, the maximum monthly average decrease in flow would also occur in June, with a 580 cfs or 12% decrease.

Denver Water Reuse Project

In 2000, Denver Water constructed a non-potable Recycling Plant near the Metro Wastewater Reclamation District Plant (Metro Wastewater Treatment Plant [WWTP]) in Denver to use its reusable supplies. The ultimate plant will be capable of delivering up to 17,500 AF/yr of water to non-potable uses in the future. The existing plant capacity is 30 millions of gallons per day, with about 7,000 AF/yr of use. In 2002, existing customers included the Cherokee Power Plant, Washington Park, City Park and Golf Course, Denver Country Club, Park Hill Golf Course, and redevelopment at Stapleton and Lowry (Denver Water 2002a). By 2011, Denver Water expanded the recycled water system to serve various schools and parks, Rocky Mountain Arsenal National Wildlife Refuge, and the Denver Zoo.

The major source of supply for the non-potable Recycling Plant is Denver Water's reusable water. For the Recycling Plant intake (direct right), Denver Water has a direct right for 70 cfs of fully consumable South Platte River water (Case No. 2001CW287). A portion of the water delivered to Denver Water's customers is not fully consumed and returns to the South Platte River as effluent from a WWTP or by groundwater return flow as a result of lawn irrigation. Return flows of non-reusable water belong to downstream water right holders and cannot be used a second time by Denver Water. However, return flows of reusable water can be used over and over again until extinction (i.e., that water is fully consumable). The main sources of reusable water in Denver Water's Collection System are:

- Blue River water delivered through the Roberts Tunnel
- Fraser River water diverted by the Meadow Creek system (the only reusable water associated with the Moffat Collection System)
- Transferred agricultural water rights on the East Slope
- Fully consumable South Platte River rights

The Metro WWTP and the Littleton-Englewood (Bi-City) WWTP are the primary return flow points of Denver Water's reusable water. Denver Water keeps track of reusable return flows and currently reuses portions of these supplies as the source of water for the non-potable recycling plant and for exchanges to upstream facilities.

Denver Water anticipates having a minimum of 27,000 AF of active gravel pit storage along the South Platte River downstream of the Metro WWTP outfall to store excess reusable effluent and return flows when available for later exchange to existing upstream reservoirs or the Recycling Plant. This includes gravel pit storage Denver Water has recently purchased as well as their North and South gravel pit complexes currently under construction. PACSM includes Denver Water's non-potable recycling plant operating at its ultimate capacity of

17,500 AF/yr and 27,000 AF of active gravel pit storage along the South Platte River available for managing its reusable supplies. The cumulative effect of reuse by Denver Water is to decrease South Platte River flows.

City of Aurora Prairie Waters Project (PWP)

The City of Aurora owns and diverts water from the Colorado and Arkansas river basins to the South Platte River Basin. Aurora also owns water decreed for municipal diversion and storage in the South Platte River Basin. Over 90% of these supplies are fully reusable. Aurora built the PWP, which enables the City to capture and beneficially use these reusable water supplies.

Information on the facilities and operations of the PWP was provided by Aurora staff and the City's website. The PWP draws water from wells adjacent to the South Platte River near Brighton for delivery to nearby recharge basins. Water is recovered from these basins via wells and conveyed via a pipeline south to Aurora's Peter Binney Water Purification Facility. The primary source of water for the project consists of Aurora's reusable return flows as well as diversions under new junior water rights. The PWP is currently capable of diverting up to 10,000 AF/yr from the South Platte River, with diversions up to 50,000 AF/yr possible in the future as the City grows, its reusable return flows increase, and infrastructure is added. The Water Infrastructure and Supply Efficiency (WISE) Partnership (as described in a subsequent section) will also make use of PWP facilities; however, the City of Aurora would take delivery of their reusable supplies through the PWP for their own use first. WISE would rely on Aurora's and Denver Water's reusable supplies that are excess to their immediate needs. Aurora currently leases a significant portion of their reusable supplies to various entities. When those leases expire, it is anticipated that Aurora would use that reusable supply as well as their remaining reusable supplies (currently uncommitted and any future additional supplies) as the primary source of supply for the PWP and WISE.

PACSM was configured to include a diversion of up to 20,000 AF/yr of Aurora's reusable supplies at the South Platte River near Henderson gage. This water will be used by Aurora as needed, with a portion also delivered to and used by the WISE participants. Reuse by Aurora through their PWP will result in a nominal decrease in South Platte River flows since a significant portion of Aurora's reusable supplies are already being used by various entities through leases. While PWP diversions will likely increase in the future, there will be a concurrent increase in return flows available for recapture as Aurora grows.

Rueter-Hess Reservoir Project

Rueter-Hess Reservoir has been constructed on Newlin Gulch, a tributary of Cherry Creek. The project, which is being implemented by the PWSD includes a dam and reservoir with a capacity of approximately 72,000 AF, a Water Treatment Plant (WTP), pump station, reservoir delivery pipelines, a diversion structure and pump station along Cherry Creek, and Denver Basin aquifer extraction and injection wells. The water sources for storage in the reservoir include water from existing Cherry Creek water rights pumped from alluvial wells, in-priority Newlin Gulch and Cherry Creek surface flows, reusable effluent from PWSD's WTP, and reusable lawn irrigation return flows diverted from Cherry Creek. PWSD's Denver Basin water will be used to provide baseflow demands to the PWSD while water from Rueter-Hess Reservoir will be used to primarily satisfy PWSD's peak summertime demands. The average annual yield from the reservoir is estimated to be 4,136 AF (Corps 2007b).

The potential effects of the project were evaluated for the Rueter-Hess Reservoir EIS and the project's net depletion to Cherry Creek was estimated to be 1,040 AF/yr. Stream flows in Cherry Creek below PWSD's diversion will be reduced on average with the reservoir; however, during periods of low flow, the project will result in more stream flow in Cherry Creek due to the contribution of the non-reusable portion of PWSD's WTP and lawn irrigation return flows. It is likely that the quantity and timing of net depletions associated with the Rueter-Hess Reservoir Project would change downstream of the project due to: (1) possible differences in the timing and magnitude of Cherry Creek Reservoir releases, (2) possible differences in downstream junior diversions and return flows along Cherry Creek and the South Platte River, and (3) potential differences in junior exchanges along the South Platte River.

PACSM currently includes historical inflows from Cherry Creek to the South Platte River based on the U.S. Geological Survey (USGS) gage, Cherry Creek at Denver, which is located at the mouth of Cherry Creek. This is considered conservative during dry years because flows in Cherry Creek below PWSD's diversion would be higher with Rueter-Hess Reservoir on line during critical low flow periods due to the contribution of additional WTP return flows and lawn irrigation return flows. While inflows from Cherry Creek to South Platte River may be less in wet years due to the Rueter-Hess Reservoir Project, the cumulative effect on South Platte River flows will likely be small since Cherry Creek is a relatively small component of the total South Platte mainstem flow in wet years.

The original Rueter-Hess Reservoir (16,200 AF) was permitted February 2004, authorizing construction of the reservoir. In 2005, PWSD proposed to enlarge Rueter-Hess Reservoir by 55,800 AF for an increase in total storage capacity from 16,200 AF to 72,000 AF (Corps 2007b). Construction of the originally permitted reservoir was partially completed in 2006, pending the outcome of the enlarged reservoir request to the Corps. PWSD received their amended Section 404 Permit for the reservoir expansion in April 2008, and construction on the enlarged reservoir was completed in 2012. The purpose of the enlarged reservoir is to provide sufficient storage of Denver Basin groundwater and the associated reuse water from Denver Basin use for selected south Denver Metropolitan area water providers. The additional sources of water to be stored in the expanded reservoir would come from existing sources (i.e., Denver Basin groundwater and associated reusable return flows). There would be no cumulative effect on South Platte River flow associated with the expansion of Rueter-Hess Reservoir.

Dry Creek Reservoir Project

The Central Weld County Water District and the Little Thompson Water District have constructed an 11,000-AF reservoir on about 300 acres of land about 4 miles east of Carter Lake. Dry Creek Reservoir is located within the Big Thompson River Basin. This reservoir would be used to store a portion of both Districts' C-BT water to improve daily operational flexibility and drought protection (ERO 2007).

This project was not included in PACSM as it is located within the Big Thompson River Basin and outside the geographic scope of the model. Cumulative effects from the Dry

Creek Reservoir Project on South Platte River flows would occur downstream of Denver Water's system and are anticipated to be minor because the project will rely primarily on trans-basin imports. Trans-basin imports would include Central Weld County Water District and the Little Thompson Water District's C-BT water. Operations of Dry Creek Reservoir would not expand the use of C-BT water but may change the timing Central Weld County Water District and Little Thompson Water District requests their C-BT water. This project would have minimal to no impact on C-BT diversions from the Colorado River.

Chatfield Reservoir Storage Reallocation Project

The Colorado Water Conservation Board (CWCB) requested that the Corps consider reallocating space within Chatfield Reservoir for water supply purposes on behalf of a group of water providers in the Denver Metropolitan area. The request was made in response to concerns on the increasing demands for water and difficulties in finding water storage sites. Congress authorized the Corps to conduct a study. The CWCB is the study sponsor; the study investigates the feasibility of reallocating water storage in an existing Federal facility, Chatfield Reservoir. Storage space in Chatfield Reservoir, located in Jefferson County southwest of Denver, would be reallocated from exclusive flood control use to joint flood control-conservation purposes including storage for municipal, industrial, agriculture, environmental restoration, recreation, and fishery habitat protection and enhancement. There are currently 12 entities involved in this project including CPW, Central CWCD, South Metro Water Supply Authority (SMWSA), Centennial Water and Sanitation District, and several other smaller water users.

The Corps released a Draft Feasibility Report and EIS for the Chatfield Reservoir Storage Reallocation Project in June 2012. The public comment period for the draft ended in September 2012, and the document was revised accordingly. The Final Feasibility Report/EIS was released for State, agency and public review August 20 through September 3, 2013. Upon finding of feasibility, the Assistant Secretary of the Army for Civil Works can approve the reallocation. The Assistant Secretary of the Army for Civil Works will issue a Record of Decision on project implementation. It is anticipated a decision on the project will be made early 2014. If approved, the project will proceed into design and implementation in accordance with legislation. Due to the overlap of publishing the Moffat Project EIS and the Chatfield Reservoir Storage Reallocation Project Feasibility Report/EIS, there was insufficient time to conduct a quantitative cumulative effects analysis.

Augmentation of Lower South Platte River Wells

Many tributary groundwater wells with junior water rights on the lower South Platte River in Colorado are being required by the State Engineer's Office to develop augmentation plans to offset the consumptive use of the wells and protect senior water rights. The augmentation plans typically involve the diversion and storage of water from the South Platte River when the relatively junior water rights are in-priority (high flows and during the winter) and/or the purchasing or leasing of trans-basin return flows. These augmentation plans would likely affect South Platte River flows (ERO 2007).

This action was not represented in PACSM. A portion of out-of-priority tributary well pumping may be replaced with reusable municipal return flows acquired from upstream entities. As municipalities like Denver and Aurora are able to more fully use their reusable effluent through their reuse projects, less reusable effluent would be available for acquisition. Therefore, it is likely that augmentation supplies would be acquired from purchased senior agricultural rights or junior water rights would be used to store South Platte River water in which case stream flows in the lower South Platte River would likely increase.

East Cherry Creek Valley Water Project

Information on the facilities and operations of the East Cherry Creek Valley Water Project was obtained from the December 2003 Water Supply Agreement between Farmers Reservoir and Irrigation Company (FRICO), the United Water and Sanitation District, and the East Cherry Creek Valley Water and Sanitation District. Under the project, water would be pumped from the Beebe Draw alluvium, treated in a new WTP and conveyed via a pipeline south connected to East Cherry Creek Valley's storage tanks in Arapahoe County. The primary sources of water for the project are changed water rights associated with the 70 Ranch located downstream on the South Platte River and shares from FRICO's Barr Lake-Milton Reservoir division. These changed water rights would be used as a substitute supply to offset depletions arising from East Cherry Creek Valley's pumping from the Beebe Draw alluvium. The first two phases of this project are anticipated to be on line prior to the Moffat Project becoming operational. East Cherry Creek Valley anticipates withdrawing approximately 6,000 AF/yr from the Beebe Draw alluvium.

There should be little change in the timing and quantity of water in the South Platte River associated with this project. The consumptive use associated with the changed water rights would be used to offset East Cherry Creek Valley's depletions and historic return flows associated with the changed rights would be maintained in quantity and timing. There could potentially be a change in flows between the location of historical return flows and the point of replacement if historic return flows are replaced using changed water rights located downstream of the project via an exchange. For example, replacement of historical return flows can be made at a downstream location if there is no injury to intervening water rights between the location of historic return flows and the point of replacement.

The cumulative effects of this project on South Platte River flows are expected to be minor. This project was not incorporated in PACSM because the majority of East Cherry Creek Valley's depletions would be offset with changed water rights and any differences in flows caused by the replacement of historical return flows via exchange would have little to no effect on flows upstream of the Henderson gage.

Cache la Poudre Flood Reduction and Ecosystem Restoration Project

The Corps is evaluating the feasibility of flood reduction and ecosystem restoration measures within a 17 mile reach of the Cache la Poudre River, in and around Greeley. Flood damage reduction efforts would be directed at a roughly 7 mile reach of the river inside Greeley city limits and would focus on protecting high-damage areas along a 2 to 3 mile reach largely east of 11th Avenue. The ecosystem restoration effort would include areas of the entire 17 mile reach with focus on the restoration of old oxbows and meander channels, available gravel pits and floodplain storage areas, and on providing connectivity through green space restoration in the flood way. The gravel pits located in the floodplain in and around Greeley would be evaluated for both their flood storage utility and their potential to improve the ecosystem of the river and its floodplain (Corps 2006).

There is currently not sufficient information available to define this action and conduct an analysis to quantify the cumulative effects of the Cache la Poudre Flood Reduction and Ecosystem Restoration Project. However, because the objective is to reduce floods along the Cache la Poudre River, cumulative effects associated with this project along the South Platte River would likely be minor.

Water Infrastructure and Supply Efficiency

The WISE Partnership is a collaborative effort among several water providers in the Denver Metropolitan area to cooperatively use existing diversion and treatment infrastructure and existing supplies to help meet a portion of their existing and future water supply needs. A fundamental goal of WISE is to reduce the reliance of SMWSA members on nonrenewable groundwater and to create a dependable, renewable surface water supply for SMWSA members. When available, Aurora Water and Denver Water would provide excess reusable return flows to SMWSA WISE participants. The WISE Partnership would be implemented in phases. WISE deliveries are anticipated to begin in 2016 (prior to the Moffat Project becoming operational).

The water available to the SMWSA WISE participants is a mix of Denver Water's and Aurora Water's excess reusable supplies. Denver Water and Aurora Water have portions of their water supplies that are not fully used in all years. These excess reusable return flows are discharged to the South Platte River at the Metro WWTP, Sand Creek and Bi-City WWTPs. The WISE Partnership would rely on existing infrastructure to deliver, treat and store water. Aurora Water's PWP will divert both Denver Water's and Aurora Water's excess reusable return flows downstream of the Metro WWTP using an alluvial well field near Brighton. The excess reusable return flows would be conveyed to the recently constructed Peter Binney Water Purification Facility and delivered to SMWSA WISE participants through the existing East Cherry Creek Valley western pipeline.

WISE deliveries are scheduled to begin in 2016 with initial deliveries of about 1,000 AF annually. The project would gradually increase deliveries to more participants in future phases as additional connecting delivery infrastructure is built and as Denver Water and Aurora demands increase over time, resulting in additional excess return flows. The WISE Project would eventually deliver an average of 10,000 AF/yr to SMWSA WISE participants; however, the supply would be variable from year to year. In some years there may be no excess reusable return flows or infrastructure capacity available for the SMWSA WISE participants because both Denver Water and Aurora Water may take delivery of their excess reusable supplies through the PWP for their own use, either fully utilizing their reusable supplies or the capacity of the PWP system.

The excess reusable water supplies that would be used by WISE were also evaluated by the Corps in the alternatives analysis for the Moffat Project. Alternatives 7, 8, 10, 11, and 14 are variations of indirect potable reuse alternatives that involve treating reusable water, storing it and delivering it back to the Moffat Collection System. Two of the five Moffat Project EIS alternatives (i.e., 8a and 10a) use the same excess reusable water supplies identified as a source of water for WISE. For a complete description of the alternatives analysis, refer to Section 2.1 and Appendix B.

The WISE Project was not incorporated in PACSM for the Moffat Project EIS because there was not sufficient information available to accurately define this action in the model. The cumulative effects of the WISE Project would be to decrease South Platte River flows below Brighton as Denver Water and Aurora continue to more fully use their excess reusable supplies for that project. However, additional flow reductions in the South Platte River are expected to be nominal because the supplies to be used would be increased future return flows from Denver and Aurora as these cities grow.

West Slope Projects

Windy Gap Firming Project (WGFP)

The Municipal Subdistrict of the NCWCD, on behalf of several of the Windy Gap Project unit holders and the Middle Park Water Conservancy District (MPWCD), is proposing to improve the firm yield from the existing Windy Gap Project water supply by constructing the Windy Gap Firming Project (WGFP). The U.S. Department of the Interior, Bureau of Reclamation (Reclamation) issued the WGFP Draft EIS in August 2008 and Final EIS in November 2011. The WGFP is anticipated to be on line by 2017.

The Subdistrict's proposed action is the construction of a 90,000 AF Chimney Hollow Reservoir located just west of Carter Lake on the East Slope. This project is anticipated to result in additional surface diversions at the Windy Gap Project diversion site on the Colorado River, which is downstream of the confluence of the Colorado and Fraser rivers. The WGFP is anticipated to generate approximately 26,000 AF/yr of firm yield for the project participants.

The cumulative effect of the WGFP would be to reduce flows in the Colorado River downstream of the Windy Gap diversion in average and wet years. Data obtained from NCWCD was generated using the WGFP model for the WGFP EIS. Model results were provided for the proposed action, Chimney Hollow Reservoir with prepositioning, which was analyzed in the EIS. Monthly WGFP model output provided by NCWCD includes Adams Tunnel C-BT and Windy Gap deliveries (separately), Windy Gap demands, Windy Gap deliveries from Chimney Hollow and Granby Reservoir to meet demands, Windy Gap pumping, Willow Creek Feeder Canal diversions, Willow Creek Reservoir end-of-month storage contents, Granby Reservoir end-of-month storage contents by account (C-BT, Windy Gap, and dead storage), and flow data at the Colorado River below Granby Reservoir gage (09019500), Colorado River below the Windy Gap diversion, Willow Creek at the confluence with the Colorado River, and Fraser River at the Granby gage (09034000). PACSM was configured to reflect similar Windy Gap demands, diversions, and deliveries. This was accomplished by modifying the demands placed at the Windy Gap and Adams Tunnel nodes in PACSM to match the data provided by NCWCD.

Coordination of Hydrologic Effects Assessments for the Moffat Project and the Windy Gap Firming Project. The Moffat Project EIS and the WGFP EIS used similar computer models to develop hydrologic information for analysis of their respective EIS alternatives. PACSM was used for the Moffat Project EIS. The WGFP model was developed using the Boyle Engineering Stream Simulation Model, which was used in combination with the Upper Colorado Water Resource Planning Model from the Colorado Decision Support System (CDSS) model. The WGFP model simulated Windy Gap Facilities (both existing and potential Windy Gap Firming Project Facilities) and East Slope C-BT facilities and operations, using divertable flows developed with the CDSS model (which covers the Colorado River drainage from the headwaters at the Continental Divide to the Colorado-Utah State line). All three models incorporate a "direct solution algorithm" (versus models that optimize allocation of water among competing uses based on "costs" that represent water right seniorities and operating rules). The primary modeling approaches incorporated in the Moffat Project and the WGFP hydrologic effects assessments are compared and contrasted below, followed by comparisons of modeling results for "Current Conditions" and for "Direct and Cumulative Effects."

- Both models are water allocation and accounting models that simulate river basin operations and account for inflows, diversions, river gains and losses, reservoir operations, and water rights using water allocation priorities. PACSM, the WGFP model, and the CDSS model all use a direct solution algorithm to allocate water according to physical, hydrological, and institutional parameters.
- The West Slope portions of PACSM and the CDSS model cover similar geographic areas, water rights, instream flow reaches and facilities including diversions, gages, and reservoirs.
- The study periods selected for both models are similar and both periods incorporate a range of wet, dry, and average years. The WGFP model study period extends 47 years from 1950 through 1996, while the PACSM study period extends 45 years from 1947 through 1991.
- Both models represent the water supply system as a series of linked nodes, which correspond to actual physical features such as diversion structures, reservoirs, instream flow reaches, demands, or stream gages. The models simulate the flow of water from node to node based on available flow, water rights, diversion or storage capacity, and water demand.
- The WGFP model operates on a monthly time step. PACSM was originally developed to operate on a monthly time step, but is now operated on a daily time step to simulate diversions and operations in a very broad geographic area involving many small streams and daily modifications to reservoir operations in response to numerous downstream minimum flow requirements, multi-party exchange agreements, and other factors. The WGFP model is supplied by a single point of diversion on a larger stream that, while affected by downstream flow requirements, is not subject to the multitude of daily operational decisions that affect Moffat Collection System operations now and into the future. PACSM is a more general use model that has applications ranging from long-term yield analysis to detailed facility operations. The purpose of the WGFP

model is focused on long-term yield analysis and reasonable assessment of hydrologic effects to comply with Federal permitting processes for the WGFP.

- Data preparation for both models required that inconsistencies between estimated baseflows and corresponding gains and losses be reconciled in situations where there is a lack of available gage data. When available, both modeling approaches typically use gaged flow data directly to estimate baseflows. However, when gage flow data are unavailable, either the missing gage flow data must be estimated and input into the baseflow calculation or the baseflow must be estimated. Differences in the techniques used to estimate baseflows can result in differences in simulated flows at locations where there are limited available gage data.
- Estimated historic ditch diversions and associated return flows can vary between the models where there is a lack of historic diversion data for modeled ditches. To estimate baseflows and simulate diversions for these ditches, historic diversions must be estimated. In addition, the timing and amount of return flows associated with agricultural and municipal use are included in the calculation of baseflows and reflected in simulated flows. To the extent that there are differences in the techniques used to estimate historic diversions and the timing and amount of return flows, there can be differences in baseflows and simulated flows.
- The WGFP model does not forecast Granby Reservoir spills and therefore simulates larger Windy Gap diversions than does PACSM, but with subsequent Granby Reservoir spills in wet years. Since the WGFP does not take into account whether Granby Reservoir is nearing a spill condition, the model simulates pumping of Windy Gap water into Granby Reservoir early in the runoff season (April and May) in some wet years that is spilled from Granby Reservoir in succeeding months (June and July). While the depletive effects on the Colorado River downstream of the Windy Gap diversion are the same on an annual basis with or without a forecasting function, the timing of flows on a monthly basis is affected in these years. PACSM incorporates a forecasting function for Granby Reservoir so that Windy Gap does not pump after Granby Reservoir reaches a certain level.
- For the WGFP cumulative effects analysis, Denver Water’s average annual demand reflected in the WGFP model is 393,000 AF/yr, which is 30,000 AF/yr higher than the average annual demand of 363,000 AF/yr reflected in PACSM for the Moffat Project cumulative effects analysis. The higher demand used in the WGFP model considers Full Use of Denver Water’s Existing System with a Moffat Project on line including use of Denver Water’s 30,000 AF Strategic Reserve. This approach in the WGFP EIS tends to overstate the cumulative effects of the two projects.

Current Conditions. Prior to initiating the modeling of EIS alternatives and cumulative effects for the Moffat Project and WGFP, the lead Federal agencies for the EISs convened a process to compare hydrologic modeling approaches and tools. This process included reviews of Windy Gap diversions, Granby Reservoir, and Adams Tunnel flows simulated in PACSM for the Moffat Project and Moffat Tunnel and Roberts Tunnel flows simulated in the CDSS and WGFP models. This process also included a detailed comparison of flows in the vicinity of the projects’ diversions, which was summarized in the technical memorandum, Comparison of Fraser River Flows Simulated in the WGFP CDSS model with those simulated in PACSM (Boyle 2005). CDSS model and PACSM results were compared for the Current Conditions model scenario, which reflects existing conditions (current project facilities, operations, consumptive and non-consumptive water rights including instream flow rights, demand levels, operating rules and constraints, and other water management considerations and preferences) throughout the Colorado River Basin in Colorado. The Current Conditions scenario includes the Windy Gap Project as it currently exists without firming storage and no Moffat Project on line. Model results were compared in the Fraser River Basin at the St. Louis Creek near Fraser gage (USGS gage 09026500), the Fraser River near Winter Park gage (USGS gage 09024000), and the Fraser River at Granby gage (09034000). These locations reflect spatially distributed locations comprised of tributary and mainstem flows in the upper and lower portions of the Fraser River Basin.

PACSM and CDSS simulated flows compare well, with excellent correlation high in the basin, which indicates both models represent diversions, return flows, and gains and losses in the Fraser River Basin in a similar manner. Both models simulate virtually the same flow at the St. Louis Creek and Fraser River near Winter Park gages. Differences in PACSM and CDSS model simulated flows are greater, lower in the Fraser River Basin at the Fraser River near Granby gage due primarily to the lack of available gage data upon which to estimate baseflows and gains and losses. However, average monthly differences at the Granby gage are still less than 4% during the runoff season from May through July, which are important months in relation to Denver Water and Windy Gap diversions.

Direct Effects and Cumulative Effects. Both models are used to simulate operations of EIS alternatives. Where possible, model data were shared between the two projects to ensure that the WGFP and Moffat Project were reflected in a similar manner in each model.

In the Draft WGFP EIS (August 2008), the direct effects analysis was based on a comparison of Current Conditions and the hydrologic conditions simulated for each EIS alternative. For the WGFP, the direct effects analysis did not include the Moffat Project since it originally was not anticipated to be on line until 2016 per the Moffat Project Purpose and Need Statement as stated in the Draft EIS. Therefore, WGFP used output from PACSM for the Current Conditions model scenario, which includes Denver Water's average annual demand at 285,000 AF/yr without a Moffat Project on line. Monthly trans-basin diversion data for the Roberts Tunnel, Gumlick Tunnel, and Moffat Tunnel were incorporated as fixed demands in the WGFP model at those structures. For its cumulative effects analysis, the WGFP modeling simulated the new Moffat Project on line with 72,000 AF of additional East Slope storage in the Moffat system and Denver Water's average annual demand at 393,000 AF/yr.

For the Moffat Project, the direct effects analysis was based on a comparison of Full Use of the Existing System and each EIS alternative. For the direct effects hydrologic analysis, the WGFP was simulated being on line prior to the Moffat Project becoming operational and output from the WGFP model was incorporated for the proposed action, Chimney Hollow Reservoir with prepositioning. Therefore, the Moffat Project used the following WGFP model output for use in PACSM: Adams Tunnel C-BT and Windy Gap deliveries (separately); Windy Gap demands; Windy Gap deliveries from Chimney Hollow and Granby Reservoir to meet demands; and Windy Gap pumping. PACSM was configured to reflect similar Windy Gap demands, diversions and deliveries by modifying the demands placed at the Windy Gap and Adams Tunnel nodes in PACSM to match the data provided from the WGFP modeling. The cumulative effects analysis was also based on a comparison of Full Use of the Existing System and each EIS alternative since reasonably foreseeable water-based actions were simulated to occur prior to the Moffat Project becoming operational and were therefore already considered in the direct effects analysis.

The cumulative effects analysis for the WGFP and Moffat Project were coordinated, and considered the same reasonably foreseeable water-based actions shown in Table 4.5.3-1. There are cases where simulated flows in the models differ primarily because Denver Water's average annual demand reflected in the WGFP model is 30,000 AF/yr higher than in PACSM. A comparison of model results shows that WGFP modeled flows are generally lower throughout the study area below Denver Water's diversion points because Denver Water's trans-basin diversions are higher in order to meet a higher demand. In addition, PACSM incorporates a Granby Reservoir forecasting function which affects Windy Gap pumping and the timing of Granby Reservoir spills in wet years. Without a Granby Reservoir forecasting function, flows in the WGFP model below Granby Reservoir and the Windy Gap diversion tend to be lower in April and May due to additional Windy Gap diversions and higher in June and July due to additional Windy Gap spills from Granby Reservoir.

Urban Growth in Grand and Summit Counties

The population in Grand and Summit counties is expected to more than double over the next 25 years, from a year-round population of about 39,000 in 2005 to about 79,000 in 2030 (ERO 2007). Most growth in Grand County is likely to occur in the Fraser River Basin while future increases in water use in Summit County would occur primarily in the Blue River Basin. Approximately 70% of the total existing and future water demands in Grand County are for water providers in the Fraser River Basin with supply sources derived from alluvial wells and surface water diversions from the Fraser River and its tributaries. The largest growth in water demands in the Fraser River Basin is expected to occur in areas served by the Grand County Water and Sanitation District No. 1, the Town of Fraser, and Silver Creek Resort. The Grand County Water and Sanitation District No. 1, which serves areas along the Fraser River to the north of Winter Park, is the single largest water provider in Grand County. The largest growth in water demands in the Blue River Basin is expected to occur in areas below Dillon Reservoir including the towns of Silverthorne, Eagles Nest, and Mesa Cortina.

Build-out municipal and industrial demands are estimated to be 16,168 AF for Grand County and 17,940 AF for Summit County as identified in the Upper Colorado River Basin Study (UPCO) (Hydrosphere 2003). The UPCO was initiated in early 1998 to identify and investigate water quantity and quality issues related to expected increases in Front Range and Colorado River headwater demands associated with continuing growth and economic development.

The timing of these future demands depends upon economic development trends in the respective service areas of the individual water providers. While it is uncertain when build-out conditions may occur for individual entities in Grand and Summit counties, the Corps concurred with Denver Water's approach to include build-out demands in PACSM to reflect the maximum potential hydrologic effect that would occur due to urban growth in these counties. PACSM was configured to reflect indoor, outdoor, and snowmaking build-out diversions, depletions, and return flows in Grand and Summit counties. The monthly distributions of the build-out demands, efficiencies, and locations and timing of snow making and outdoor use return flows were based on data obtained for the UPCO. Increased water use and wastewater discharges are expected to result in changes in stream flow and water quality and contribute to cumulative effects. Because build-out demands in Grand and Summit counties are included in PACSM, the associated hydrologic effects are evaluated and presented in Appendix H.

Based on PACSM results, municipal and domestic water supplies in the Fraser River Basin were adequate for existing levels of water demand, but several water providers would experience shortages under build-out demands as shown in Table 4.5.3-3. Shortages would be most severe for the Grand County Water and Sanitation District and the Town of Fraser, averaging 358 AF/yr and 247 AF/yr, respectively. These shortages would occur primarily in the fall and winter months as a result of lack of physical supply and Denver Water's upstream diversions. Other water supply systems that would experience shortages to a lesser degree under build-out conditions, include the towns of Hot Sulphur Springs and Kremmling, Winter Park West Water and Sanitation District, and Silver Creek Resort.

PACSM results showed that most water providers in Summit County have sufficient water supplies to cover current levels of demand. However, under build-out demands, nearly two-thirds of the providers are expected to have demands that exceed their current water rights and/or water availability as shown in Table 4.3.1-3. The largest shortages are predicted for the Blue River upstream of Dillon Reservoir, Snake River upstream of Dillon Reservoir, and Tenmile Creek upstream of Dillon Reservoir.

Reduction of Xcel Energy's Shoshone Power Plant Call

The Shoshone Hydropower Plant, which is owned by Xcel Energy, has a senior water right to divert 1,408 cfs from the Colorado River 8 miles east of Glenwood Springs. Denver Water and Xcel Energy have negotiated an agreement to periodically invoke a relaxation of the Shoshone Call at times when flows are less than 1,408 cfs at the point of diversion. The agreement to relax the call could result in a one-turbine call of 704 cfs, which would be managed in such a way to avoid a Cameo Call. The Cameo Call refers to a senior water right located near Grand Junction. The Shoshone Call could be increased above 704 cfs as needed to keep the Cameo water rights satisfied. The Shoshone Call relaxation could be invoked if, in March, Denver Water predicts its total system storage to be at or below 80% on July 1 that year, and the March 1 Natural Resources Conservation Service (NRCS) forecast for Colorado River flows at Kremmling or Dotsero are at or below 85% of average. The Shoshone Call relaxation could be invoked between March 14 and May 20.

Denver Water would make available 15% of the "net water" stored or diverted by Denver Water by virtue of the call relaxation for Xcel Energy. Net water is water stored, less water subsequently spilled, after filling. In addition, Denver Water would make available 10% of the net water stored or diverted by Denver Water by virtue of the call relaxation to West Slope entities. The West Slope beneficiaries and the timing and amount of deliveries are not specified, but the agreement states how the timing and amount of deliveries will be decided. The term of this agreement is from January 1, 2007 through February 28, 2032.

Table 4.3.1-3
Summary of Grand County and Summit County Demands and Shortages for Full Use with a Project Alternative with RFFAs (2032)

Grand County Average Annual Demands and Shortages (AF/yr)															
Water Provider		Current Conditions (2006)		Difference in Build-out Shortage with the Alternatives											
				Full Use of the Existing System		Proposed Action with RFFAs		Alternative 1c with RFFAs		Alternative 8a with RFFAs		Alternative 10a with RFFAs		Alternative 13a with RFFAs	
Node	Diversion Name	Demand	Shortage	Demand	Shortage	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence
1065	Columbine Lake WD	157	0	303	0	0	0	0	0	0	0	0	0	0	0
1070	Town of Grand Lake	198	0	1,262	1	1	0	1	0	1	0	1	0	1	0
1400	Hot Sulphur Springs	113	0	1,668	70	70	0	70	0	70	0	70	0	70	0
1700	Town of Kremmling	443	0	889	33	32	0	32	0	32	0	32	0	33	0
2130	Winter Park Rec and W&S (Indoor)	149	0	500	6	6	0	6	0	6	0	6	0	6	0
2390	Winter Park Rec. (Snowmaking)	195	0	470	0	0	0	0	0	0	0	0	0	0	0
2360	Grand County W&SD	688	0	3,713	358	364	6	364	6	364	6	364	6	364	6
2620	Winter Park West W&SD	455	0	617	29	29	0	29	0	29	0	29	0	29	0
2640	Town of Fraser	310	0	3,326	247	247	0	247	0	247	0	247	0	247	0
2850	Silver Creek Resort	186	0	2,951	18	18	0	18	0	18	0	18	0	18	0
2880	Town of Granby	229	0	465	6	6	0	6	0	6	0	6	0	6	0

Table 4.3.1-3 (continued)
Summary of Grand County and Summit County Demands and Shortages for Full Use with a Project Alternative with RFFAs (2032)

Summit County Average Annual Demands and Shortages (AF/yr)															
Water Provider		Current Conditions (2006)		Difference in Build-out Shortage with the Alternatives											
				Full Use of the Existing System		Proposed Action with RFFAs		Alternative 1c with RFFAs		Alternative 8a with RFFAs		Alternative 10a with RFFAs		Alternative 13a with RFFAs	
Node	Diversion Name	Demand	Shortage	Demand	Shortage	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence
4100	Arapahoe Basin Snowmaking	45	1	299	60	60	0	60	0	60	0	60	0	60	0
4115	Keystone-Montezuma Domestic	0	0	30	5	5	0	5	0	5	0	5	0	5	0
4135	Keystone Snake River Snowmaking	626	151	1,159	181	181	0	181	0	181	0	181	0	181	0
4140	Keystone Gulch	0	0	78	9	9	0	9	0	9	0	9	0	9	0
4145	Keystone Golf Course	174	0	175	0	0	0	0	0	0	0	0	0	0	0
4150	Keystone Ranch	273	0	279	0	0	0	0	0	0	0	0	0	0	0
4120	Snake River WD	613	2	1,903	24	24	0	24	0	24	0	24	0	24	0
4225	East Dillon WD	292	0	623	1	1	0	1	0	1	0	1	0	1	0
4065/ 4070/ 4090	Town of Breckenridge	2,330	1	3,506	2	2	0	2	0	2	0	2	0	2	0
4085	Breckenridge Golf Course	169	2	169	3	3	0	3	0	3	0	3	0	3	0
4055	Breckenridge Ski Resort	541	0	809	1	1	0	1	0	1	0	1	0	1	0

Table 4.3.1-3 (continued)
Summary of Grand County and Summit County Demands and Shortages for Full Use with a Project Alternative with RFFAs (2032)

Summit County Average Annual Demands and Shortages (AF/yr)															
Water Provider		Current Conditions (2006)		Difference in Build-out Shortage with the Alternatives											
				Full Use of the Existing System		Proposed Action with RFFAs		Alternative 1c with RFFAs		Alternative 8a with RFFAs		Alternative 10a with RFFAs		Alternative 13a with RFFAs	
Node	Diversion Name	Demand	Shortage	Demand	Shortage	Shortage	Difference	Shortage	Difference	Shortage	Difference	Shortage	Difference	Shortage	Difference
4170	Copper Mountain W&SD	266	0	1,111	18	18	0	18	0	18	0	18	0	18	0
4175/ 4180	Copper Mountain (outdoor & snowmaking)	488	0	850	0	0	0	0	0	0	0	0	0	0	0
4205	Town of Frisco	846	0	1,975	0	0	0	0	0	0	0	0	0	0	0
4290	Dillon Valley demand	327	0	402	0	0	0	0	0	0	0	0	0	0	0
4295	Town of Dillon	330	0	701	0	0	0	0	0	0	0	0	0	0	0
4340	Buffalo Mountain / Mesa Cortina	297	0	744	0	0	0	0	0	0	0	0	0	0	0
4350	Town of Silverthorne	754	0	2,124	0	0	0	0	0	0	0	0	0	0	0
4400	Eagle's Nest	331	0	1,005	0	0	0	0	0	0	0	0	0	0	0

Notes:
RFFA = reasonably foreseeable future action
W&S = water & sanitation
W&SD = Water & Sanitation District
WD = Water District

The future operation of the Shoshone Call reduction was not reflected in PACSM because it currently is a temporary arrangement that would only occur under certain conditions which are difficult to include in the model because the conditions are based on forecasted values. Therefore, the hydrologic effect of this action is discussed qualitatively.

The triggers that permit a relaxation of the Shoshone Call are based on forecasts of Denver Water's total system storage and the March 1 NRCS forecast for Colorado River flows at Kremmling or Dotsero. Historical Denver Water reservoir contents and stream flow forecast data were relied on to evaluate how often the call relaxation would have potentially been invoked from 1947 through 2002. Because historical forecasts of Denver Water's July 1 reservoir contents are lacking, historical July 1 reservoir contents were reviewed for the period from 1947 through 2002. Historical reservoir contents provide a reasonable indication of whether the first trigger condition would have been met. Denver Water's total system storage was less than 80% on July 1 in 1951, 1954, 1955, 1956, 1957, 1963, 1964, 1965, 1977, 1978, and 2002. While Denver Water's total system storage was less than 80% on July 1 in 1957 and 1965, it was over 90% later in July and August in both of those years. Both 1957 and 1965 were relatively wet years; however, flows were above average primarily after the March through May period affected by the call relaxation. Without historical forecast data, it is difficult to predict whether the Shoshone Call relaxation would have been invoked in years 1957 and 1965.

The second trigger condition that must be met to invoke the call relaxation involves NRCS forecast data for Colorado River flows at Kremmling or Dotsero. Prior to 2005, stream flow forecasts for the Colorado River at Kremmling were not yet made by the NRCS. Therefore, the analysis relied on stream flow forecasts for the Colorado River at Dotsero that exist for the period from 1969 through 2005. Since Dotsero forecast data does not exist prior to 1969, the evaluation of whether the Shoshone Call would have been invoked during the period from 1947 through 1968 only considered Denver Water's historical storage contents. From 1969 through 2005, there were only 3 years that Denver Water's total system storage on July 1 was less than 80%: 1977, 1978, and 2002. Of those years, only 1977 and 2002 had March forecasts that were less than 85% or average.

Based on historical July 1 storage contents in Denver Water's reservoirs and available stream flow forecast data for the Colorado River at Dotsero, the Shoshone Call relaxation may have been invoked in about 8 to 10 years during the period 1947 through 2002, or roughly 1 out of every 6 to 7 years. Since 2002, the Shoshone Call was relaxed from March 14 through May 20 inclusive in 2003 in accordance with a March 21, 2003 agreement between Denver and the Colorado River Water Conservation District (CRWCD). The agreement to relax the call in 2003 was not based on the triggers specified in the current agreement. In addition, there was no formal call relaxation in 2004 since the Shoshone Power Plant was not in a position to call for water from March 10 through July 12 inclusive because the plant was down for maintenance.

The relaxation of the Shoshone Call would allow diverters that would otherwise be called out to divert water in-priority even if they are junior to the Shoshone Power Plant water rights. Because more diversions would be made in-priority, releases from reservoirs such as Green Mountain, Wolford Mountain, and Williams Fork Reservoir for exchange or substitution purposes would also be less. Increased in-priority diversions and reduced reservoir releases for exchange and/or substitution would decrease flows in the upper Colorado River Basin during the relaxation period.

A Shoshone Call relaxation may occur most frequently under the No Action Alternative compared to Current Conditions (2006) and the action alternatives. Without additional storage on line and the increase in Denver Water's demand, the trigger condition, which is based on forecasts of Denver Water's total system storage, would likely be met more frequently under the No Action Alternative. Changes in diversions and reservoir releases under a Shoshone Call relaxation would likely be similar under the No Action Alternative compared to Current Conditions and the action alternatives, however, the frequency the Shoshone Call would be relaxed would likely be greater under the No Action Alternative.

The magnitude and timing of flow reductions attributable to a Shoshone Call relaxation could vary widely from year to year and would depend on many factors including stream flows, storage contents, project operations, and bypass/instream flow requirements. Therefore, it is difficult to quantify potential hydrologic effects associated with a call reduction. Data from 2003 and 2004 have been relied on to characterize the magnitude of hydrologic effects that have occurred historically due to a reduction in the Shoshone Call. The Shoshone Call was relaxed in 2003 under an agreement for that year only, and in 2004 when the Shoshone plant was non-operational for scheduled maintenance. Table 4.3.1-4 summarizes the gains to key upstream entities due to the relaxation of the Shoshone Call in 2003 and 2004 from March 14 through May 20 inclusive, as quantified by Denver Water and reviewed by Reclamation, the CRWCD, and others. In 2003 and 2004 the flow reductions due to a relaxation of the Shoshone Call totaled 21,234 AF and 26,841 AF, respectively.

Table 4.3.1-4
Historical Gains from Shoshone Call Relaxation
March 14 through May 20 Inclusive

Project/Water Rights	2003 Gains[1,2] (AF)	2004 Gains[1] (AF)
Continental Hoosier Project (1929 and 1948 Rights)	1	212
Green Mountain Reservoir	6,415	6,190
Wolford Mountain Reservoir	2,036	5,708
Moffat Tunnel[3]	388	1,124
Williams Fork Reservoir (1935 Right)	1,350	5,869
Roberts Tunnel	974	6,833
Dillon Reservoir	2,027	315
Windy Gap	7,850	0
Homestake Project	193	590
Total	**21,234**	**26,841**

Notes:
[1]Gains were calculated as if the Shoshone Calls were 1,300 and 1,500 cfs, respectively, as opposed to 1,250 cfs and 1,408 cfs; therefore, gains are overestimated slightly.
[2]Meadow Creek Reservoir gained 432 AF in 2003 due to the Shoshone Call relaxation. Gains in 2004 were not quantified.
[3]The gains to the Moffat Tunnel were realized at Williams Fork Reservoir because exchange releases from Williams Fork Reservoir were not required. This water would have been diverted through the Moffat Tunnel regardless of the Shoshone Call relaxation; however, because the call was relaxed, those diversions were not out-of-priority and therefore did not require exchange releases from Williams Fork Reservoir.

The key projects/water rights that benefited from a reduction of the Shoshone Call in 2003 and 2004 included the Continental-Hoosier Project, Green Mountain Reservoir, Wolford Mountain Reservoir, Denver Water (Moffat Tunnel, Williams Fork Reservoir, Roberts Tunnel, and Dillon Reservoir), Windy Gap, and the Homestake Project.

When the Shoshone Call is reduced, the projects/facilities listed in Table 4.3.1-4 would be able to divert more water in-priority even if they are junior to the Shoshone Power Plant water rights. Because more diversions would be made in-priority, releases from reservoirs such as Green Mountain, Wolford Mountain, and Williams Fork reservoirs for exchange or substitution purposes would be less. Increased in-priority diversions and reduced reservoir releases for exchange and/or substitution would decrease flows in the upper Colorado River Basin primarily in the Williams Fork River, Muddy Creek, the Blue River, and the Colorado River mainstem below the Windy Gap diversion during the relaxation period. The only changes in flows outside of the relaxation period would be due to differences in substitution releases from Wolford Mountain and Williams Fork reservoirs. However, differences in substitution releases would not change flows in the Colorado River below the confluence with the Blue River since these releases are made in place of Green Mountain Historic User's Pool releases. Note that flows in the Fraser River Basin during the relaxation period would likely not be affected because Denver Water diverts regardless of the Shoshone Call and exchanges with releases from Williams Fork Reservoir to cover out-of-priority diversions. The Shoshone Agreement does not provide additional water to the Moffat Collection System because Denver Water retains enough water in Williams Fork Reservoir to exchange against out-of-priority diversions in the Moffat Collection System. The relaxation of the Shoshone Call did increase Denver Water's ability to exchange water to Dillon Reservoir and Roberts Tunnel in 2003 and 2004 thereby increasing the supply in Denver Water's South System. Flows in the Fraser River Basin could potentially be higher outside of the relaxation period if Denver Water increases bypasses in a manner similar to 2003 as part of the 10% water owed to West Slope entities.

Additional storage in Williams Fork Reservoir could result in additional exchanges to Denver Water's Blue River system in the year the call is relaxed and possibly subsequent years. Williams Fork Reservoir benefited from a reduction of the Shoshone Call in both 2003 and 2004. Williams Fork Reservoir stored more water in-priority and had to release less water to exchange against Denver Water's out-of-priority diversions at Dillon Reservoir and Roberts Tunnel. In addition, 2003 would have been a substitution year and the 2004 substitution would have been greater had it not been for the Shoshone Call relaxation. Denver Water relies on Williams Fork and Wolford Mountain reservoirs to replace (substitute) what is owed to Green Mountain Reservoir if it does not fill. With a call reduction, Green Mountain Reservoir is in-priority to store more in-flow below Dillon Reservoir, therefore, the call reduction can reduce the amount owed by Denver Water. A reduction in substitution releases would reduce flows below Williams Fork and Wolford Mountain reservoirs primarily in the fall when these releases are typically made. Had 2003 and 2004 been substitution years, the benefits to Denver Water shown in Table 4.3.1-4 would have been less and substitution releases would have been required. The reach of river affected by increased diversions to storage and reduced substitution releases from Williams Fork and Wolford Mountain reservoirs is the Williams Fork River below Williams Fork Reservoir, Muddy Creek below Wolford Mountain Reservoir, the Blue

River below Green Mountain Reservoir, and the Colorado River below the confluence with the Williams Fork River. Differences in substitution releases would not change flows in the Colorado River below the confluence with the Blue River.

Changes in Releases from Williams Fork and Wolford Mountain Reservoirs to Meet USFWS Flow Recommendations for Endangered Fish in the 15-Mile Reach (“10,825 Water”)

The Programmatic Biological Opinion for the recovery of endangered fish includes a provision for East Slope and West Slope water users to split equally the delivery of 10,825 AF of water (colloquially referred to as “10,825 Water”) to the 15-mile reach of the Colorado River east of Grand Junction. An agreement exists between Denver Water, the CWCB, and the U.S. Fish and Wildlife Service (USFWS), for the interim provision of water to the 15-mile reach of the Colorado River near Grand Junction as part of the recovery program. A similar agreement exists between CRWCD, CWCB, and the USFWS. These agreements provide for the total release of 10,825 AF of water annually from both Williams Fork and Wolford Mountain reservoirs (5,412.5 AF from each reservoir) to meet USFWS flow recommendations for the 15-mile reach of the Colorado River.

These contracts expired in 2010. The agreements were extended in 2010 for an additional 3-year term, with a possible extension of two additional 1-year terms upon mutual agreement with the USFWS. Denver Water and the CRWCD have said they do not plan to continue making these releases from Williams Fork and Wolford Mountain reservoirs in the future. PACSM was configured so that releases of water from Williams Fork and Wolford Mountain reservoirs for the endangered fish in the 15-mile reach do not occur since this action will occur prior to the Moffat Project becoming operational. This action affects the timing and quantity of reservoir storage and releases and the flows in Williams Fork River and Muddy Creek below the reservoirs. Fish releases from these reservoirs have historically been made in the late summer and fall when flows drop below the USFWS flow recommendations. When fish releases are not made from Williams Fork and Wolford Mountain reservoirs, flows in the Williams Fork River, Muddy Creek, and Colorado River downstream of the confluence with these tributaries would be less by a commensurate amount in the fall. The reduction in fish flow releases could be offset by a corresponding change in the amount of water stored in these reservoirs on average. Less water would need to be stored during the runoff season to replace these releases. Therefore, flows in the Williams Fork River, Muddy Creek, and Colorado River downstream of the confluence with these tributaries would be higher when Williams Fork and Wolford Mountain reservoirs fill and spill. Changes in Williams Fork and Wolford Mountain reservoir storage and releases due to this action would affect the timing of flows below these reservoirs, but would have little effect on the annual quantity of flow on average.

In April 2012, Reclamation issued a Final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for a permanent source of the 10,825 Water. Water users and Reclamation are currently discussing the terms and conditions of water contracts that would formalize the release of water from Ruedi and Granby reservoirs. If these contracts are not finalized prior to the expiration of the existing contracts that use Williams Fork and Wolford Mountain reservoirs, interim measures would have to be implemented. The source and location of any releases of the 10,825 Water in the interim period between when the agreements expire and permanent sources are implemented has not been determined.

Potential interim sources of water could include temporary use or leasing of water from existing facilities. Potential new, permanent water sources for release of the 10,825 Water were evaluated in the 10,825 Water Supply Study, which was a collaborative study initiated by a broad coalition of East and West Slope stakeholders. Since the modeling was completed for the Moffat Project EIS, the 10,825 Water Supply Study has led to the identification of a preferred alternative, which consists of releases from Ruedi and Granby reservoirs. Under the preferred alternative, 5,412 AF of water would be released from Ruedi Reservoir each year, and an additional 5,412 AF would be released from Granby Reservoir from mid-summer through the fall, at a fixed schedule that is designed to optimize habitat in the upper Colorado River below Granby Reservoir. Release schedules were analyzed for dry, average, and wet years, as shown on Table 2 in the Final EA. Also, available excess storage capacity in Green Mountain and Wolford Mountain reservoirs may be utilized (if necessary) to re-time the scheduled releases from Granby Reservoir and optimize benefits in the 15-mile reach of the Colorado River.

While the 10,825 Water releases will no longer be made from Williams Fork and Wolford Mountain reservoirs, half of the 10,825 AF/yr release will be made from Granby Reservoir under the preferred alternative. This will offset approximately half of the flow reduction currently reflected in PACSM that would occur in the fall in the Colorado River below the confluence with Williams Fork River and Muddy Creek due to the cessation of 10,825 Water releases from Williams Fork and Wolford Mountain reservoirs.

Wolford Mountain Reservoir Contract Demand

According to the CRWCD, the demand for contract water out of Wolford Mountain Reservoir is expected to increase in the future. CRWCD staff indicated there is currently about 8,750 AF/yr of available contract water in Wolford Mountain Reservoir and that the full 8,750 AF/yr would likely be contracted for in the future. In addition, MPWCD has 3,000 AF/yr of contract water in Wolford Mountain Reservoir. Under the Clinton Reservoir Agreement, Grand County water users agreed to provide Denver Water with 613 AF/yr of replacement water, which reduces MPWCD's contract water to 2,387 AF/yr. The CRWCD indicated that MPWCD's 2,387 AF/yr would likely be contracted for in the future, and that the total future build-out demand for contract water from Wolford Mountain Reservoir would be 11,137 AF/yr.

It was assumed that the full 11,137 AF/yr would be contracted prior to the Moffat Project becomes operational, in which case, PACSM was configured to make releases from Wolford Mountain Reservoir to meet the full contract demand when depletions (consumptive use) are estimated to be out-of-priority. The specific entities that would contract for this water in the future and the locations of the depletions have not been identified. Thus, PACSM was configured so that Wolford Mountain Reservoir would release to cover monthly contract depletions during the winter months (September through March) and in summer months of dry years. In addition, releases would be made in several average years depending on whether the Shoshone Power Plant rights were estimated to be calling.

This action affects the timing and quantity of Wolford Mountain Reservoir storage and releases and the flows in Muddy Creek below the reservoir. Because releases for contract demands increase in the future, flows in Muddy Creek would increase on average by a commensurate amount primarily during winter months and in summer months of dry years. However, more water would be stored during the runoff season to replace these releases, so flows during runoff would decrease on average below the reservoir. The hydrologic effects associated with this action were evaluated and presented in Chapter 4.

Expiration of Denver Water's Contract with Big Lake Ditch in 2013

The Big Lake Ditch is a senior irrigation right in the Williams Fork Basin that diverts below Denver Water's Williams Fork Collection System and above Williams Fork Reservoir. Big Lake Ditch diversions are currently delivered for irrigation above Williams Fork Reservoir and for use in the Reeder Creek drainage, which is a tributary of the Colorado River. Return flows associated with irrigation in the Reeder Creek drainage, return to the Colorado River below the confluence with the Williams Fork.

In 1963, Denver Water entered into a contract with Bethel Hereford Ranch Inc., which owned majority of the interest in and operated the Big Lake Ditch, whereby Denver Water purchased such the interests. Bethel Hereford was granted a 40-year lease to continue its operation under the condition that the acquired interests in Big Lake Ditch water rights are not exercised if it interfered with the needs of Denver Water. The 1963 agreement was superseded by a 1998 agreement, which extended the operation of the Big Lake Ditch through 2013, and provided more detail on the conditions under which Denver Water would need the water. After the contract expires in 2013, as modeled in the Full Use of the Existing System scenario, the owner can no longer use these interests on the owner's lands, and return flows historically diverted under the interests will not return to Reeder Creek.

As part of the Colorado River Cooperative Agreement (CRCA), Denver Water will participate in a joint study of how to maintain historic agricultural uses of the Big Lake Ditch so as to maximize environmental benefit while preserving the yield Denver Water expects from retiring the water right. If a balance between the three needs (environmental, agricultural, and yield) can be found, Denver Water would implement the results of the study when the Moffat Project becomes operational. Until the study is completed, Denver Water plans to develop a short-term agreement for operations of the Big Lake Ditch beyond 2013. However, for the purpose of the EIS, Big Lake Ditch operations were modeled assuming the existing 1998 agreement expires in November 2013 for Full Use of the Existing System, the No Action Alternative, and the action alternatives.

Prior to 2013, in dry years, the 1998 agreement specifies that the acquired interests in the Big Lake Ditch water rights will not interfere with Denver Water's ability to divert water at the existing Williams Fork Collection System or operate whenever specified storage levels are not anticipated at Williams Fork and Dillon reservoirs. Apart from this, the ditch can divert water, even in dry years. The non-exercise of the interests in Big Lake Ditch rights during portions of dry years allows Denver Water to divert additional water to storage in Williams Fork Reservoir at times that the reservoir water rights are in-priority. In these years, diversions through the Big Lake Ditch and the corresponding consumptive use of the water for irrigation is reduced, and irrigation return flows to Reeder Creek, a tributary to the Colorado River, are also reduced. This affects the timing of flows in the Colorado River below the confluence with the Williams Fork River. Likewise, after 2013, diversions through the Big Lake Ditch and the corresponding consumptive use of the water for irrigation under the interests is eliminated, and irrigation return flows to Reeder Creek will be eliminated. Depending on the year type, this may increase or decrease the overall gain of water to the Williams Fork River and Colorado River below the confluence with the Williams Fork River. Also, the timing of flows would change.

In the Full Use of the Existing System scenario, PACSM was configured so the Big Lake Ditch no longer diverts water for irrigation in the Reeder Creek drainage because Denver Water's contract with Big Lake Ditch expires prior to the Moffat Project becoming operational. This action affects the timing and quantity of flows in Williams Fork River and the Colorado River. The abandonment of all Big Lake Ditch diversions to the Reeder Creek Basin would allow Denver Water to capture additional water from Williams Fork River for storage in Williams Fork Reservoir when its Williams Fork Reservoir water rights are in-priority. Big Lake Ditch diversions would decrease, deliveries to the Reeder Creek drainage would be curtailed, and all Big Lake Ditch return flows would accrue to the Williams Fork River instead of the Colorado River below the confluence with the Williams Fork River. The change in Big Lake Ditch operations would result in approximately 10,000 AF/yr less diverted and a corresponding increase in flows on average in the Williams Fork River Basin. Return flows to the Reeder Creek Basin would decrease by approximately 8,000 AF/yr. Changes in flow would be greatest from June through October when differences in Big Lake Ditch depletions and return flows are greatest. The additional inflow to Williams Fork Reservoir would allow Denver Water to divert additional water to storage in Williams Fork Reservoir at times the reservoir water rights are in-priority. The additional water stored in Williams Fork Reservoir does not result in increased diversions to the East Slope through the Moffat Tunnel by Denver Water. The non-exercise of Denver Water's interest in the Big Lake Ditch rights does not affect Moffat Collection System operations because Denver Water operates its system to retain sufficient water in Williams Fork Reservoir to fully exchange to the Moffat Collection System. The additional supplies in Williams Fork Reservoir could increase Denver Water's ability to exchange to Roberts Tunnel and Dillon Reservoir. Depending on water availability, flows in the Williams Fork River and Colorado River below the confluence with the Williams Fork River may increase or decrease due to the effects of this action.

Colorado Springs Utilities' Substitution and Power Interference Agreements at Green Mountain Reservoir

Reclamation has entered into a Green Mountain Reservoir Substitution Agreement with Colorado Springs Utilities (Springs Utilities) and a Power Interference Agreement with Springs Utilities and Western Area Power Administration (WAPA). Springs Utilities is obligated to provide substitution water for diversions from the Blue River in years when Green Mountain Reservoir does not fill. Springs Utilities previously did this on an annual basis subject to the terms and conditions of the Blue River Decree. In May and October 2003, Springs Utilities entered into Memorandum of Agreement (MOA), which formalized a long-term substitution plan and set forth the terms and conditions among the parties to the MOAs regarding substitution operations by Springs Utilities. The 2003 MOAs specifically approve the additional substitution water sources of Wolford Mountain and Homestake reservoirs, which are beyond the sources authorized in the Blue River Decree.

The Substitution and Power Interference Agreements with Reclamation allow Springs Utilities to comply with the Blue River Decree by approving the 2003 MOAs as Springs

Utilities' substitution operation plan. Reclamation conducted an EA that evaluated the proposed action, which was the effect of operating under 2003 MOAs. The EA was completed and a FONSI was issued by Reclamation in December 2008.

Under the approved action, Reclamation has entered into a 40-year Substitution Agreement with Springs Utilities that authorizes Springs Utilities' substitution plan according to the terms and conditions set forth in the 2003 MOAs. The elements of the May 2003 MOA that are specific to the approved action are the use of Wolford Mountain Reservoir and Homestake Reservoir as sources of replacement water in a manner consistent with the terms and conditions of the 2003 MOA. Another component of the approved action is a contract water exchange, whereby Springs Utilities may provide up to 250 AF stored in the upper Blue Reservoir to the River District each year in return for a like-amount of water stored in Wolford Mountain Reservoir. The 250 AF in upper Blue Reservoir is intended for water users in the Blue River Basin including Summit County, Vail, Summit Resorts, and Breckenridge. A storage account in an amount up to 1,750 AF is maintained by the River District at Wolford Mountain Reservoir for the benefit of Springs Utilities to store upper Blue Reservoir water exchanged into Wolford Mountain Reservoir. In addition, a long-term Power Interference Agreement was formalized with Reclamation, WAPA, and Springs Utilities. Under the agreement, Springs Utilities will compensate for lost hydropower with power generated from their own facilities, at a time and location determined by WAPA. Springs Utilities reserves the right to pay WAPA monetarily or with power. PACSM was configured consistent with the terms and conditions of the approved action.

The hydrologic effects of the approved action would be minimal. Stream segments affected by the approved action that are within the Moffat Project study area include the Blue River downstream of Dillon Reservoir, Williams Fork River downstream of Williams Fork Reservoir, Muddy Creek downstream of Wolford Mountain Reservoir, and the Colorado River downstream of the confluence with Williams Fork River. Under Springs Utilities' approved action, more water will be released from their accounts in Wolford Mountain and Homestake reservoirs while Denver Water's substitution releases for Springs Utilities from Williams Fork Reservoir or Dillon Reservoir would decrease. During substitution years, the average monthly flow decreases for the river segments listed above would be less than 1 cfs.

Colorado River Cooperative Agreement

Denver Water and 17 West Slope parties have developed a comprehensive agreement known as the Colorado River Cooperative Agreement. This multi-party agreement provides a framework for a wide range of actions to benefit water supply and the environment on both sides of the Continental Divide. The CRCA was made public in 2011 and became effective on September 26, 2013. In addition to the 17 West Slope signatories and the environment, an additional 25 towns, water districts and ski areas on the West Slope would obtain benefits from the CRCA. Some of the provisions in the CRCA are effective upon execution while others would be implemented when the Denver Water receives acceptable permits necessary for construction of the Moffat Project or when the Moffat Project becomes operational. In the CRCA, Denver Water has committed to provide certain enhancements to the aquatic environment in the Fraser, Williams Fork, and upper Colorado rivers in part to address impacts that may be associated with existing operations by Denver Water, Grand County, and other water users. The following are some of the key environmental provisions of the CRCA, when fully implemented. A complete version of the CRCA can be found on Denver Water's web site: http://www.denverwater.org/SupplyPlanning/Planning/ColoradoRiverCooperativeAgreement/.

- Environmental Water – Denver Water will make available 1,000 AF of water each year from its Fraser River Collection System for environmental purposes in Grand County, at times and locations requested by Grand County. This water will be matched with up to an additional 1,000 AF from Williams Fork Reservoir and 2,500 AF of carry-over storage in that reservoir for environmental purposes at the request of Grand County. The additional water in Williams Fork Reservoir is a result of a decrease in exchange from Williams Fork Reservoir to the Moffat Tunnel as a result of the 1,000 AF of additional bypass flows. Subject to the provisions of the CRCA, Denver Water also committed to make an additional 375 AF/yr available, which would otherwise be diverted through the Moffat Tunnel, for use by certain Grand County water users. Any portion of an additional 375 AF not needed by Grand County water users may also be available for environmental purposes.
- Learning by Doing (LBD) Cooperative Effort – The purpose of this cooperative effort is to use available resources, including the resources provided by the CRCA, to protect and where possible, restore or enhance the aquatic environment in the Fraser, Williams Fork and upper Colorado rivers. The LBD effort will be implemented through an Intergovernmental Agreement between Denver Water, Grand County, Colorado River Water Conservation District, and MPWCD. In addition, Colorado Parks and Wildlife (CPW) (previously called Colorado Division of Wildlife), Trout Unlimited, and the NCWCD-Municipal Subdistrict will participate on the LBD Management Committee. The LBD Cooperative Effort would rely on the information contained in the Grand County Stream Management Plan and would continue to adapt and improve it to guide and prioritize restoration/enhancement opportunities.
- U.S. Forest Service (USFS) Bypass Flows – Denver Water agrees to not reduce USFS bypass flows in the Fraser River Basin during a drought unless Denver Water has banned all residential lawn watering in its service area (which Denver Water has never done to date). This equates to about 2,000 AF of additional water for the aquatic environment during drought conditions.
- Funding for Grand County – Denver Water will pay $11 million toward projects for aquatic habitat improvements, addressing nutrient loading in the Fraser River, paying for the cost of pumping Windy Gap water for environmental purposes, and other environmental enhancements and specified water supply projects in Grand County.
- Funding for Summit County – Denver Water will contribute $11 million toward projects such as WWTP improvements, environmental enhancements, and local water and sewer projects.
- Exchanges to Fraser River and Williams Fork River – Denver Water agreed not to operate exchanges from Dillon Reservoir to Williams Fork Reservoir and to the Fraser River and Williams Fork River Diversion Projects if such exchanges would impact

instream flow water rights, even though some of these exchanges were operated as early as 1966.

- The CRCA parties will implement a "Shoshone Outage Protocol" during an unscheduled outage of the Shoshone Power Plant to mitigate the potential adverse effects of the absence of the Shoshone call by operating reservoirs as if the call were still on the river. The parties also agree to not oppose the existing 2007 Shoshone call relaxation agreement between Denver Water and Xcel Energy and to support renewal of the agreement.
- Denver Water will place $1 million into a fund to protect Wild & Scenic River outstanding resource values in the upper Colorado River.
- Big Lake Ditch – Denver Water will participate in a joint study of how to maintain historic agricultural uses of the Big Lake Ditch so as to maximize environmental benefit while preserving the yield Denver Water expects from retiring the water right. If a balance between the three needs (environmental, agricultural, and yield) can be found, Denver Water would implement the study.

Fish and Wildlife Enhancement Plan

As part of the environmental evaluation of the Moffat Project, Denver Water prepared a Fish and Wildlife Mitigation Plan and a Fish and Wildlife Enhancement Plan (Enhancement Plan) in accordance with Code of Federal Regulations Section 37-60-122.2 (refer to Final EIS Appendix M for a copy of these plans). Both plans were adopted by the Colorado Wildlife Commission on June 9, 2011 and subsequently by the CWCB on July 13, 2011. The Fish and Wildlife Mitigation Plan is the official State position on mitigation of impacts to fish and wildlife resources. The Enhancement Plan was submitted voluntarily by Denver Water to improve existing conditions in the aquatic environment in the Colorado River downstream of Windy Gap. The main component of the Enhancement Plan is the upper Colorado River Habitat Project (Habitat Project) to be funded and implemented jointly with NCWCD-Municipal Subdistrict, and CPW. Other entities such as Grand County, Trout Unlimited, and landowners along the Colorado River will participate in designing and implementing the stream restoration program and may also contribute funding. The Enhancement Plan includes $7.5 million in funding for the Habitat Project to improve the existing conditions in approximately 17 miles of the Colorado River from the Windy Gap diversion to the Kemp-Breeze State Wildlife Area downstream of the confluence with the Williams Fork River. The Enhancement Plan will become effective once Denver Water and NCWCD-Municipal Subdistrict have received acceptable permits for the Moffat Project and WGFP, respectively.

4.3.2 Future Land-based Actions

Future land-based actions considered for cumulative effects analysis in the Moffat Project area include construction of residential, commercial, and industrial structures; construction and expansion of city, county, State, and Federal roads and highways; and gravel mining. The following descriptions of future land-based actions provide information on regional development trends that, in turn, provide context for Moffat Project impacts.

Population Growth and Development Along the Front Range

Continued population growth and urban development is expected to occur in the Denver Metropolitan area served by the Moffat Project regardless of the proposed construction and operation of a Project alternative. Denver Water estimates that by 2050, 1.9 million people will be using their supplies (Denver Water 2002a).

The regional population is expected to increase from almost 3 million in 2005 to more than 4 million in 2035, an increase of almost 50% (DRCOG 2011).

Between 1990 and 2000, the Denver region's urban area grew from 410 square miles to 500 square miles. The region's urban growth area boundaries generally define where urban development will occur over the next 25 years. The annual change in urbanized area for the period 2006-2035 is estimated at 1%. In 2006 the boundary/area contained approximately 730 square miles of urban development, which would increase to more than 990 square miles by 2035.

The Denver Regional Council of Governments (DRCOG) is comprised of representatives from 51 counties and municipalities in the greater Denver Metropolitan area. The 2035 Metro Vision Plan describes DRCOG's long-range plan to manage growth within the Denver Metropolitan area. The plan is designed for use by local governments as they make decisions about land use planning and development. The key components and vision to be implemented as the Denver Metropolitan area population urbanization increases include:

- 10% increase in urban density between 2000 and 2035.
- 50% of new housing and 75% of new employment located in urban centers between 2005 and 2035.
- Protect a total of 880 square miles of State and local parks and open space by 2035.

Other components include maintaining freestanding communities, promoting rural town centers, implementing transportation improvements and preserving environmental quality.

Transportation Improvements

DRCOG's 2035 Metro Vision Regional Transportation Plan identified several transportation elements necessary for supporting existing and future growth challenges. The plan identifies the needs for large-scale transportation improvements throughout the Denver Metropolitan area in order to accommodate population growth, and subsequently, increased traffic. In general, transportation improvements would include: regional rapid transit rail, new or widened roadways, additional interchanges, various modes of rapid transit services, multi-modal transportation options, increased services for persons with special mobility needs, transportation transfer hubs, and additional or improved freight services (DRCOG 2011).

The greatest determinant of future growth near the Leyden Gulch Reservoir site is transportation network improvements. State Highways (SHs) 72 and 93 are major arterials for the northwest Denver Metropolitan region. Portions of the Leyden Gulch Reservoir site study area were within the Northwest Corridor EIS study area, a joint project between the Federal Highway Administration (FHWA) and the Colorado Department of Transportation (CDOT). The Northwest Corridor Draft EIS and subsequent planning studies examined long-range transportation needs in the northwest Denver Metropolitan area. Several project alternatives include a new or expanded north-south route, some of which would create an interchange or intersection improvements near the junction of SHs 72 and 93 (CDOT 2008). Although CDOT and FHWA stopped work on the Northwest Corridor EIS in mid-2008 due to a lack of funding for construction and the absence of a consensus among local governments, SHs 72 and 93 remain major arterials in that area and are candidates for future expansion. In 2008, following CDOT's decision to stop work on the Northwest Corridor Study, the Jefferson Parkway Public Highway Authority was established with a mission of completing ". . . . the last unbuilt portion of the Denver metropolitan beltway."

The Jefferson Parkway Public Highway Authority is a group consisting of the City of Arvada, Jefferson County, and the City and County of Broomfield. Transportation improvements near the Leyden Gulch Reservoir site would increase the likelihood of commercial and industrial/office development around the intersection of SHs 72 and 93. However, it is assumed that any transportation improvement in this general area is likely to improve access to the Leyden Gulch Reservoir site vicinity and may result in increased development pressure.

Other major transportation EIS projects occurring in the general area of the Moffat Project include the State Highway 36 Improvement Project and the Regional Transportation District Northwest Rail Project.

Site-specific Development

Gross Reservoir

The recreational and scenic qualities of Gross Reservoir provide amenities for year-round and part-time residents in houses dispersed on 35-acre lots and in rural subdivisions. Recent parcel database queries indicate that there are no new or proposed subdivision developments on private lands within or adjacent to the Gross Reservoir study area. However, a limited amount of large-lot single-family mountain home development is expected to continue on private lands in the Project vicinity.

Leyden Gulch Reservoir Site

The Leyden Gulch Reservoir site is within the expected growth corridor of the northwest Denver Metropolitan area and will experience change in the near future (estimated 1 to 5 years). The intersection of SHs 72 and 93 is zoned for commercial development by the City of Arvada and several subdivisions are planned in the region. Although the majority of the Project vicinity remains unincorporated, it is highly probable that residential growth will continue westward from the cities of Westminster, Arvada, Wheat Ridge, and Golden, with commercial and industrial development along SHs 72 and 93.

Desired and future land uses in the Leyden Gulch Reservoir site are defined in the North Plains Community Plan (Jefferson County 2011), a contributing document to the Jefferson County Comprehensive Master Plan (Jefferson County 2012), and the City of Arvada Comprehensive Plan (City of Arvada 2005). The primary county plan objective for the area west of SH 93 is to maintain a feeling of openness by preserving viewsheds and important wildlife habitat and through the acquisition of additional open space properties. Park-like settings and graduated building heights and setbacks are recommended for any development west of SH 93. These developments would be subject to similar viewshed protection guidelines. All areas in the vicinity of the Leyden Gulch Reservoir site appear to be stable, with the exception of the area immediately east of SH 93 at the intersection with SH 72, known as the Jefferson Center Urban Redevelopment Area.

Jefferson Center Urban Renewal Plan

The Jefferson Center Urban Renewal Plan aims to stimulate development of underutilized lands (approximately 2,000 acres) east of SH 93 at SH 72 by creating a commercial and industrial center (Arvada Urban Renewal Authority 2009). These uses may promote additional traffic near the Leyden Gulch Reservoir site and may subsequently increase local development pressures. This plan is also reflected in the North Plains Area Plan, which was adopted on November 16, 2011. The North Plains Area Plan is a chapter of the Jefferson County Comprehensive Master Plan (Jefferson County 2012).

South Platte River Facilities

The South Platte River Facilities study area is located in the City of Brighton Rivers and Lakes Joint Planning Area (City of Brighton 2009). This joint City/County planning area was established to keep "the land open for farming, public open space and minimizing area of regional flood hazards." Most land in this joint planning area is largely expected to remain unincorporated although some areas will be appropriate for annexation. The City of Brighton Land Use Plan anticipates that areas associated with the South Platte River Facilities will remain as agriculture or other non-urban uses (City of Brighton 2006).

Jefferson County Open Space Master Plan

As a result of growth trends, acquiring the foregrounds for views of the Front Range mountain backdrop is an overarching priority for Jefferson County, as stated in their Open Space and Parks Five-Year Master Plan (Jefferson County 2008). All of the Leyden Gulch Reservoir site is identified as a "potential open space preservation area" and two of the Trails 2000 segments are planned across the study area to enhance trail connectivity to the Coal Creek Canyon and the open space properties in northern Jefferson County. Denver Water owns a majority of property at the Leyden Gulch Reservoir site. If Denver Water determines that the site is not needed for a reservoir site, which may be independent of the Moffat Project, Jefferson County would have the option to purchase the site as established in a Memorandum of Understanding. Jefferson County has purchased lands west of the reservoir site to preserve as open space. However, unincorporated lands to the south and east of the proposed reservoir site remain in private ownership. Boulder County owns open space north of SH 72.

Rocky Flats Environmental Technology Site

The former Rocky Flats Environmental Technology Site is located approximately 4 miles northeast of the Leyden Gulch Reservoir site. Under the Rocky Flats National Wildlife Refuge (NWR) Act of 2001, the 6,240-acre Rocky Flats Environmental Technology Site became the Rocky Flats NWR following certification from the U.S. Environmental Protection Agency (EPA) that cleanup and closure have been completed. The refuge entered U.S. Fish and Wildlife Service stewardship in 2007 following the EPA's determination that corrective actions had been completed.

A Final Comprehensive Conservation Plan (CCP) for the Rocky Flats NWR was released in 2005 and will guide management of refuge operations, habitat restoration, and visitor services for 15 years. The CCP emphasizes both wildlife and habitat conservation along with a moderate level of wildlife-dependent public use. Refuge-wide habitat conservation will include management of native plant communities, removal and revegetation of unused roads and stream crossings, management of deer and elk populations, and protection of Preble’s meadow jumping mouse habitat. Restoration will strive to replicate pre-settlement conditions. Visitor use facilities will include about 16 miles of trails, a seasonally staffed visitor contact station, trailheads with parking, and developed overlooks. Currently, the refuge remains closed to the public due to a lack of appropriations for refuge management operations, but it continues to protect important wildlife resources, including critical habitat for the Federally threatened Preble’s meadow jumping mouse.

In 2011 a plan to expand the refuge and exchange a corridor with a width of up to 300 feet along the refuge’s eastern boundary was approved by the refuge manager. The land exchange would add more than 600 acres to the refuge and grant a transportation corridor to the Jefferson Parkway Public Highway Authority. (See prior discussion on Transportation Improvements.)

Worthing Pit

Worthing Pit is located in Adams County, southwest of the Exit 36 interchange (E-470 and Old Brighton Road), adjacent to the eastern edge of the South Platte River. The Adams County Regional Park is currently under construction on the west bank of the South Platte River and will feature a golf course, fishing opportunities, a nature preserve, segments of the South Platte Trail, volleyball, outdoor concert facilities, and a rodeo arena.

4.4 CLIMATE CHANGE AND WATER RESOURCES

4.4.1 Relation of Rising Ambient Air Temperature and Water Resources in the West

Numerous studies have been conducted on the relationship between climate change and water resources in the West. Most climate models project that air temperatures will continue to rise in the West. In Colorado, air temperatures have increased about 2 degrees Fahrenheit in the past 30 years and future winter projections indicate fewer extreme cold months, more extreme warm months, and more strings of consecutive warm winters (National Research Council of the National Academies 2007; Western Water Assessment 2008). Results from hydrological modeling of the impact of rising temperatures on water resources in mountainous western regions vary widely (Garfin and Lenart 2007; Hoerling and Eischeid 2007; IPCC 2008; Woodhouse 2007). Similarly, modeled variability in projected annual precipitation trends is high in Colorado (Western Water Assessment 2008). This variation is primarily due to the lack of sufficient water-flow data (e.g., snowmelt and runoff data in high mountain basins) and difficulty in modeling weather patterns (Diaz 2005). Additionally, global climate models do not completely represent the complexity of Colorado's mountainous topography (Western Water Assessment 2008).

Many scientific studies have predicted an increase in air temperatures, resulting in changes in the composition of winter precipitation and the timing of spring snowmelt. As air temperatures rise the West could receive more winter precipitation in the form of rain versus snow and the snow that does accumulate would melt earlier in the spring than in past years. In Colorado, the onset of stream flows from melting snow has shifted earlier by two weeks between 1978 and 2004 and the timing of runoff is projected to shift earlier in the spring (Western Water Assessment 2008). If this were to occur, it is likely that the yield of the Moffat Collection System would decrease due to existing capacity constraints. The Moffat Collection System canals and tunnels are only capable of transporting a certain amount of water before reaching hydraulic limitations. Additionally, South Boulder Creek is only capable of transporting approximately 1,200 cubic feet per second at Pinecliffe before flooding concerns arise. If runoff were to occur in a condensed timeframe, it is likely that hydrological limitations in the Moffat Collection System could decrease the Board of Water Commissioners' (Denver Water's) yield. Furthermore, a condensed timeframe for runoff would likely mean a reduction in the number of days Denver Water's water rights are in priority to divert water. This could result in Denver Water building additional replacement sources to ensure an adequate supply of water for its customers.

4.4.2 Climate Change and Water Managers

It is estimated that nearly 75 percent of water supplies in western States are derived from snowmelt. Consequently, current water resource management of western rivers is based on the knowledge that much of the runoff to reservoirs and lowlands occur early in the warm season, as water demands for irrigation and other uses are at their greatest (USGS 2005b). Western States Water Council predicts that storage will become the primary issue related to western water supplies in the future (Woodhouse 2007). Scientific studies have predicted that since the stream flow may peak earlier, evapotranspiration may be higher and droughts may be longer and more severe, it is also likely that water demands would increase in correlation with rising air temperatures. This situation may require water managers to address greater extremes in water systems in the foreseeable future. Water managers may best cope with the combination of these anticipated changes by flexible operations that can incorporate increasing amounts of new scientific information as it becomes available (Garfin and Lenart 2007; Woodhouse 2007; USDA 2010; USGS 2009b). In a report entitled "Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation," it was reported that "climate change will affect Colorado's use and distribution of water and that water managers and planners currently face specific challenges that may be further exacerbated by projected climate changes" (Western Water Assessment 2008).

While climate change and global warming may be considered reasonably foreseeable; but currently, there is no generally-accepted scientific method to correlate air temperature changes with incremental changes in stream flow or reservoir levels. The Western Water Assessment report included a caution that the assessment and quantification of specific climate change impacts on water resources is beyond the scope of their study (Western Water Assessment 2008). The Colorado Water Conservation Board has embarked on a water availability investigation to identify and address potential sources of water supply in Colorado. The study considers climate variability and potential effects on supplies in Colorado in an effort to help water managers in making resource management decisions while acknowledging the degree of climate change uncertainty (CWCB 2012). Thus, hydrologic changes in response to global climate change have not been quantitatively described in this Environmental Impact Statement (EIS).

Denver Water has evaluated climate change scenarios in relation to water supply risks and their Strategic Water Reserve but, as previously discussed, although climate models show general agreement that temperatures are likely to increase in the west, there is less agreement about how this change will influence water resources. In a recent journal article (Woodhouse 2007), Denver Water described the scientific information that would be necessary to more adequately assess the impacts of global climate change on the water resources they manage. Their climate information "wish list" includes:

- Data on changes of timing and annual volume of stream flow
- Watershed scale precipitation change data
- A hydrologic model for the Colorado River Basin that incorporates climate data in order to more carefully evaluate the effects of various climatic regimes and potential management strategies
- A better understanding of how climate change may impact watershed land cover (e.g., vegetation changes, fires, etc.)

Research on information needs, tools, and procedures to more accurately predict the effects of climate change on stream flow are ongoing. The U.S. Army Corps of Engineers and the U.S. Department of the Interior, Bureau of Reclamation jointly published a report (Brekke 2011) that evaluated the data needs and water management tools required for the long-term water planning efforts of the water management community. The document identified methods for categorizing tools and information needs for further research on the issue of climate change and long-term water planning. The Water Research Foundation recently published a study titled "Joint Front Range Climate Change Vulnerability Study" (Water Research Foundation 2012) that focused on procedures for combining climate science with hydrologic simulations to predict stream flow trends. Study results indicated broad variability and uncertainty in future stream flow that mimicked the variability and uncertainty associated with the climate models themselves. As with many studies on climate change, the studies advance the science, but point toward the need for more research before estimates on stream flow response to climate change can be utilized with accuracy and certainty.

In summary, changes in snowpack and stream flow timing associated with climate change may affect reservoir operations including flood control and storage. Additionally, changes in the timing and magnitude of runoff may also impact the functioning of diversion and conveyance structures (Western Water Assessment 2008). However, a generally-accepted scientific method by which current climate change information is translated into predictable stream flow changes and assimilated into water supply decision-making is still not available. Therefore, quantitative climate change-induced stream flow predictions are not evaluated in this EIS. As stated in the Purpose and Need described in Chapter 1, Denver Water needs improved operational flexibility of the Moffat Collection System, including being able to respond to unpredictable global climate changes and adjusting operations in response to new scientific information.

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4.5 ACTIONS NOT CONSIDERED REASONABLY FORESEEABLE FUTURE ACTIONS

A summary of potential future actions that did not meet the criteria for reasonably foreseeable future actions (RFFAs), defined in Section 4.1, are discussed below.

4.5.1 Water-based Actions

Projects determined to be potential future actions but not reasonably foreseeable, as defined by National Environmental Policy Act of 1969, as amended, include Parker Water and Sanitation District's (PWSD's) transfer of agricultural water rights, the construction of Wolcott or Sulphur Gulch reservoirs for storage and release of 10,825 acre-feet (AF) for endangered fish in the Colorado River, the Yampa Pumpback Project, the Flaming Gorge Pipeline Project, the Colorado River Return Project (CRRP), and the Blue River Pumpback and Wolcott Reservoir Project.

Parker Water and Sanitation District's Transfer of Agricultural Water Rights

PWSD is currently conducting a study to evaluate the effects of transferring and using agricultural water rights along the lower South Platte River as a water supply source for Rueter-Hess Reservoir. There is no information on the potential implementation date of this action nor is there sufficient information available to define this action and conduct an analysis to quantify cumulative effects. This action was not considered reasonably foreseeable.

Regional Water Supply Project

The Regional Water Supply Project consists of a plan proposed by the Million Conservation Resource Group to deliver water from Flaming Gorge Reservoir and the Green River via a pipeline along the Interstate 80 utilities corridor across Wyoming to serve Front Range communities in Colorado. The total estimated volumes from the two diversion points are approximately 165,000 AF from Flaming Gorge Reservoir and 85,000 AF from the Green River during a dry year. Flaming Gorge Reservoir stores up to 3.8 million AF of water for the benefit of upper basin states including Colorado, New Mexico, Utah, and Wyoming under the Colorado River Compact. Other water users in the State, including the Colorado River Water Conservation District, Northern Colorado Water Conservancy District, the Board of Water Commissioners (Denver Water), Aurora, South Eastern Colorado Water Conservancy District, Colorado Springs Utilities, and Pueblo Board of Water Works, have voiced concerns over the project regarding its potential effects on flows available to the upper basin states to meet Compact obligations and how the contract would be administered in a shortage.

This project was not considered reasonably foreseeable because there is not reasonable certainty as to the likelihood of this action occurring. The project does not identify who would put the water to beneficial use and there is not sufficient information available to define this action and conduct an analysis to quantify the cumulative effects of the Flaming Gorge Pipeline Project. The U.S. Army Corps of Engineers (Corps) issued a Notice of

Intent to prepare an Environmental Impact Statement (EIS) to analyze the effects of the proposed project in March 2009. The Corps terminated the EIS and the Section 404 Permit application on July 22, 2011.

Yampa Pumpback Project

The Northern Colorado Water Conservancy District board of directors is conducting a multi-basin investigation to identify facilities and associated costs for the transfer of water from rivers in northwest Colorado to the Front Range area to meet potential future water supply shortfalls. The purpose of this study is to identify and evaluate alternatives to dry-up of agricultural land in northeastern Colorado. The investigation looked at potential options for diverting water from the Yampa River below Maybell, which is downstream of all major Yampa water rights for irrigation, municipal, and industrial uses. The project would divert about 20 percent (%) of the flows in the Yampa River that now leaves Colorado. The study indicated that the project could yield more than 300,000 acre-feet per year (AF/yr) for delivery through a series of pumps, pipes, and tunnels to the Front Range area. The project would include a 500,000 AF off-stream reservoir built near Maybell. The project could benefit at least five river basins within the State, including the Yampa, North Platte, South Platte, Arkansas, and Colorado basins, by providing water directly or by exchange (NCWCD 2006).

The Yampa Pumpback Project is not reasonably foreseeable because it has been studied only at a feasibility level, would require further analysis to determine the most likely configuration, there is little certainty it would occur, does not identify who would put the water to beneficial use, and there is little information available to quantify its effects.

Colorado River Return Project

The CRRP concept is to pump available flows from the Colorado River near the Colorado-Utah State line upstream for use in the Colorado, South Platte, and Arkansas river basins. The configurations studied in the Colorado River Return Reconnaissance Study (Boyle 2003b) considered three flow rates of 250,000, 500,000, and 750,000 AF/yr. Pipeline alignments considered in the Reconnaissance study followed three general corridors and ranged in length from 184 to 268 miles. The least-cost construction costs for the range of capacities ranged from $3.7 billion to $8.7 billion. The required time to bring the CRRP on line is estimated to range from a minimum of 10 years up to 27 years given the requisite design, permitting, and funding requirements.

The CRRP is not reasonably foreseeable because it has been studied only at a feasibility level, would require further analysis to determine the most likely configuration, there is little certainty it would occur, does not identify who would put the water to beneficial use, and there is little information available to quantify its effects.

Blue River Pumpback with Wolcott Reservoir

The Blue River Pumpback and Wolcott Reservoir study considered hydrology, water supply availability, water quality, and construction costs of two potential pumpback options. These options, known as the Everist Pond Pumpback and the Green Mountain Reservoir Pumpback, would both pump Blue River water upstream to Dillon Reservoir. Both options would also include construction of the Eagle-Colorado Reservoir (also known as "Wolcott Reservoir") on Alkali Creek in the Eagle River Basin, to provide new supplies and replace some of the current uses of Green Mountain Reservoir. The two pumpback options are separate projects and include different sizing of Wolcott Reservoir and result in different project yields.

The pumpback and storage projects are not reasonably foreseeable because they have been studied only at a feasibility level, would require further analysis to determine the most likely configuration, there is little certainty they would occur, do not identify who would put the water to beneficial use, and there is little information available to quantify their effects.

4.5.2 Land-based Actions

Conversion of Agricultural Lands

Throughout the Front Range agricultural farmland has decreased significantly in the past 20 years, and likely will continue to decrease, due to commercial and residential development pressures and the transfer of irrigation water to municipal and industrial uses. The timing and location of the future agricultural land conversions cannot be accurately determined and is considered speculative.

Ongoing Gravel Mining

It is likely that gravel mining will continue along the South Platte River in and near the Denver Metropolitan area. Many of these gravel mines will be converted to water storage lakes following mining. At this time, it is not possible to accurately predict the specific location of future gravel mines because the development and location of the mining is subject to market forces.

Local Planning Boundaries

Several municipalities and communities in the cumulative effects study area have identified expected future growth boundaries, and subsequently, provide a context for future growth and development in the region. However, these boundaries do not meet the criteria for reasonably foreseeable activities because these boundaries are not representative of specific projects. Many local governments are also pursuing additional water supplies to respond to these anticipated planning boundaries.

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4.6 EVALUATION OF TOTAL ENVIRONMENTAL EFFECTS

4.6.1 Surface Water

The affected environment for surface water is described for Current Conditions (2006) in Section 3.1. This cumulative impacts analysis evaluates the changes in surface water due to flow changes associated with each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs) and past actions such as diversions.

Water-based actions in the South Platte and Colorado river basins that were considered for the cumulative effects analysis are shown in Table 4.6.1-1. Several of these actions are anticipated to be on line by the time the Board of Water Commissioners' (Denver Water's) projected demands are estimated to begin to exceed system supplies. The hydrologic effects of these projects in combination with the Moffat Project alternatives are discussed in the following sections. The description of hydrologic changes is based on comparisons against Current Conditions (2006). RFFAs that were not included in the hydrologic modeling cumulative effects analysis (see Description of the Model discussion below) because there was not sufficient information available to model the flow impact were addressed qualitatively in Section 4.3.

Table 4.6.1-1
Water-based Actions Considered for Cumulative Effects Analysis

Water-based Action	Included in PACSM	Addressed Qualitatively
REASONABLY FORESEEABLE WATER-BASED ACTIONS		
East Slope Projects		
1) Halligan-Seaman Water Supply Project		✓ Downstream of Henderson gage
2) Northern Integrated Supply Project	Partially	
3) Denver Water Reuse Project	✓	
4) Aurora Prairie Waters Project	✓	
5) Rueter-Hess Reservoir (16,200 AF and enlarged 72,000 AF reservoir)		✓
6) Dry Creek Reservoir Project		✓
7) Chatfield Reservoir Storage Reallocation Project		✓
8) Augmentation of Lower South Platte Wells		✓ Downstream of Henderson gage
9) East Cherry Creek Valley Project		✓ Downstream of Henderson gage
10) Cache la Poudre Flood Reduction and Ecosystem Restoration Project		✓ Downstream of Henderson gage
11) Water Infrastructure and Supply Efficiency		✓

Table 4.6.1-1 (continued)
Water-based Actions Considered for Cumulative Effects Analysis

Water-based Action	Included in PACSM	Addressed Qualitatively
West Slope Projects		
12) Windy Gap Firming Project	✓	
13) Urban Growth in Grand and Summit Counties	✓	
14) Reduction of Xcel Energy's Shoshone Power Plant Call		✓
15) Changes in Releases from Williams Fork and Wolford Mountain Reservoirs to Meet USFWS Flow Recommendations for Endangered Fish in the 15-Mile Reach	✓	
16) Wolford Mountain Reservoir Contract Demand	✓	
17) Expiration of Denver Water's Contract with Big Lake Ditch in 2013	✓	
18) Colorado Springs Utilities' Substitution and Power Interference Agreements at Green Mountain Reservoir	✓	
19) 10,825 Water Supply Alternatives		✓
WATER-BASED ACTIONS CONSIDERED NOT REASONABLY FORESEEABLE FUTURE ACTIONS		
20) Parker Water and Sanitation District Transfer of Agricultural Water Rights		
21) Regional Watershed Supply Project		
22) Yampa Pumpback Project		
23) Colorado River Return Project		
24) Blue River Pumpback with Wolcott Reservoir		

Notes:
AF = acre-feet
PACSM = Platte and Colorado Simulation Model
USFWS = U.S. Fish and Wildlife Service

In the South Platte River Basin, most RFFAs rely on water supplies from trans-mountain imports or transferred agricultural water. Projects like the Halligan-Seaman Water Supply Project, which rely to a large degree on transferred agricultural rights, should not affect South Platte River flows since historical return flows must be maintained to prevent injury to downstream water users. Projects that will have the greatest cumulative effects on South Platte River flows when added to the effects of the Moffat Collection System Project include the Denver Water Reuse Project, Water, Infrastructure and Supply Efficiency (WISE) Project, City of Aurora Prairie Waters Project (PWP), and Northern Integrated Supply Project (NISP). The Denver Water Reuse Project, WISE, and Aurora's PWP will decrease South Platte River flows as Aurora and Denver Water make more use of their reusable return flows. NISP would decrease flows in the Cache la Poudre River and the lower South Platte River due to the Project's reliance on the development of existing and/or new conditional water rights for diversion and exchange of native river water.

In the Colorado River Basin, the Windy Gap Firming Project (WGFP) and Shoshone Call reduction would likely have the greatest cumulative effect on flows when added to the effects of the Moffat Project. The effects of the WGFP would occur primarily in above average and wet years due to additional diversions at the Windy Gap diversion site on the Colorado River. The WGFP and Moffat Project would decrease flows in average and wet years and then primarily during the wettest months of the year. The hydrologic effects of the Shoshone Call reduction would occur primarily in dry years, because more diversions would be made in priority upstream of Shoshone, and releases from Green Mountain, Williams Fork, and Wolford Mountain reservoirs for exchange and substitution purposes would be less.

The methods and tools used to generate hydrologic information and analyze potential impacts on surface water hydrology are described in the following sections.

Description of the Model

Denver Water's Platte and Colorado Simulation Model (PACSM), which is a water allocation computer model, was used as the tool to generate hydrologic information for the analysis of the Environmental Impact Statement (EIS) alternatives. PACSM was used to generate hydrologic output, including stream flows and reservoir data. Denver Water staff developed each of the model scenarios assessed and executed PACSM. The input, operations, and results of PACSM were reviewed and verified by the U.S. Army Corps of Engineers' (Corps) third-party contractor. Detailed information on the study period, network configuration, natural flow hydrology, water rights, physical attribute data, precipitation and evaporation rates, diversions and demands, and operational rights included in PACSM were evaluated.

PACSM is an integrated system of computer programs used to simulate stream flows, reservoir operations, and water supply availability. PACSM simulates operations of the raw water supply systems belonging to Denver Water and others, within portions of the South Platte and Colorado river basins. The model accounts for inflows, diversions, river gains and losses, reservoir operations, and water rights implementation using water allocation priorities. The physical system and water rights represented in the model are administered in accordance with the Prior Appropriation Doctrine and contractual and operating agreements such as Senate Document 80 and the Blue River Decree. The water supply system is represented in the model as a system of linked nodes, which correspond to actual physical features such as diversion structures, reservoirs, instream flow requirements, demands, trans-basin imports, or stream gages. The model allocates water to a node based on available flow, water rights, diversion or storage capacity, and water demand. The model uses a daily time step.

The geographic area currently modeled in PACSM extends from the headwaters of the Colorado River and its tributaries along the Continental Divide downstream to the 15-Mile Reach upstream of the confluence with the Gunnison River, and from the headwaters of the South Platte River, including the South, Middle and North forks, downstream to the Kersey gage. PACSM generates output data at specific locations throughout the study area called nodes. Refer to Figure 3.0-1 for node locations.

The study period for PACSM extends 45 years from water years 1947 through 1991 and includes a variety of hydrologic conditions, such as dry, wet, and average years.

Model Scenarios Assessed

The following scenarios were evaluated using PACSM:

- Current Conditions (2006)
- Full Use of the Existing System with RFFAs
- Action alternatives with RFFAs
- No Action Alternative with RFFAs

Section 4.6.1 describes the total environmental effects on surface water resources that would result from the Moffat Project in combination with other RFFAs. Therefore, this section presents the total surface water effects that are anticipated to occur by 2032. Total environmental effects are based on a comparison of hydrologic data for Current Conditions (2006) and each of the action alternatives and No Action. It is appropriate to compare each of the action alternatives and the No Action Alternative to modeled Current Conditions (2006) as opposed to historical conditions since the hydrology associated with Current Conditions (2006) reflects the current administration of the river, demands, infrastructures, and operations.

Hydrologic impacts directly or indirectly related to implementing an action alternative are based on a comparison of hydrologic data for Full Use of the Existing System and each of the action alternatives. Effects that are specifically attributable to the Moffat Project are discussed in Chapter 5.

- **Current Conditions (2006)** – Current Conditions (2006) reflects conditions in the year 2006, including demands, facilities, agreements, operations, and administration of the Colorado and South Platte river basins. Under the Current Conditions (2006) scenario, Denver Water's average annual demand is 285,000 acre-feet (AF). The purpose of the Current Conditions (2006) scenario is to model Denver Water's existing water rights and facilities under the hydrologic conditions that existed throughout the study period (1947 through 1991). In addition, the operations of all existing reservoirs and diversion facilities are simulated for the entire study period, regardless of when they came on line.
- **Full Use of the Existing System with RFFAs** – Full Use of the Existing System reflects the operation of Denver Water's existing system at an average annual unrestricted demand of 345,000 AF. Full Use of the Existing System does not include a Moffat Project on line. The estimated firm yield of Denver Water's system is 345,000 AF/yr not including use of the Strategic Water Reserve. Denver Water's existing system is capable of meeting an average annual demand of 345,000 AF, therefore, the hydrologic effects associated with additional diversions that would occur as Denver Water's demand grows to that level are not an impact of the proposed Moffat Project. Denver Water's projected demands are estimated to begin to exceed system supplies (not including the Strategic Water Reserve) in year 2022 based on PACSM results. Under this scenario, Denver Water would maximize the yield of their existing water supplies using their current facilities and infrastructure. This scenario also

includes other RFFAs that would occur between 2006 and 2022. These projects are described in Section 4.3. Denver Water is not responsible for mitigating for the effects of other RFFAs since they are not caused by the Moffat Project.

- **Action Alternatives with RFFAs** – The action alternatives reflect the operation of Denver Water's system in year 2032 with the Moffat Project implemented and other RFFAs that would occur between 2006 and 2032. Denver Water's average annual demand in year 2032 is estimated to be 363,000 AF (379,000 AF/yr demand less the 16,000 AF/yr demand met by conservation measures). Each action alternative provides 18,000 AF/yr of new firm yield. Model parameters and assumptions included in PACSM for each action alternative are summarized in a technical memorandum entitled "Review of Modifications Made to PACSM to Reflect the Baseline Scenario and EIS Alternatives" (Boyle 2006a).
- **No Action Alternative with RFFAs** – The No Action Alternative scenario reflects the operation of Denver Water's system in year 2032 at an average annual demand of 363,000 AF without any modifications to their existing facilities or water rights. The No Action Alternative also includes other RFFAs that would occur between 2006 and 2032.

Model Simulation Output

PACSM was used to simulate each of the scenarios discussed in the previous section. Daily model output generated by PACSM for Denver Water's primary facilities and the affected river segments includes stream flow, reservoir content, elevation, and surface area data. Hydrologic data that have been used to analyze surface water and other resource impacts are summarized in Appendix H as described below.

- Appendix H-1 includes hydrologic output comparing Current Conditions (2006) and Full Use of the Existing System with each of the EIS alternatives. The Current Conditions (2006) scenario was compared with the alternatives to display the total environmental effects that would occur from the Moffat Project in combination with other RFFAs. Appendix H-1 includes average, dry- and wet-year average end-of-month storage contents, elevations, and surface areas for Williams Fork, Dillon, Wolford Mountain, Gross, Antero, Eleven Mile Canyon, Cheesman, and Leyden Gulch reservoirs and gravel pit storage (included in Alternatives 8a and 13a). Appendix H-1 also summarizes average monthly flows, diversions, and reservoir outflow at several locations of interest for average, dry, and wet conditions.
- Appendix H-2 and Appendix H-3 include hydrologic output comparing Full Use of the Existing System with the action alternatives. Hydrologic model output associated with the action alternatives was compared against similar output generated for Full Use of the Existing System to assess impacts on surface water hydrology that are directly or indirectly related to implementation of an action alternative.
  - Appendix H-2 includes average, dry- and wet-year average end-of-month storage contents, elevations, and surface areas for Williams Fork, Dillon, Wolford Mountain, Gross, Antero, Eleven Mile Canyon, Cheesman, and Leyden Gulch reservoirs and gravel pit storage (included in Alternatives 8a and 13a) for Full Use

of the Existing System and all the alternatives, including the No Action Alternative. Note that reservoir surface area data are included in Appendix H-2; however, changes in surface area and associated impacts are described under the cumulative impacts sections for other resources throughout Chapter 4.

  – Appendix H-3 summarizes average monthly flows, diversions, and reservoir outflow at several locations of interest for average, dry, and wet conditions.

- Appendix H-4 includes average daily hydrographs at several locations of interest for average, dry, and wet conditions for Current Conditions (2006), Full Use of the Existing System, and the action alternatives, including the No Action Alternative.
- Appendix H-5 includes flow duration curves at several locations of interest for Current Conditions (2006), Full Use of the Existing System, and the action alternatives, including the No Action Alternative.
- Appendix H-6 presents the maximum daily flow change, and the percentage of days that flow changes would occur for Current Conditions (2006), Full Use of the Existing System, and the action alternatives. Appendix H-6 also includes daily hydrographs for a series of dry years followed by a wet year.
- Appendix H-7 presents average annual flows, diversions, and reservoir outflow for average, dry, and wet conditions for Current Conditions (2006), Full Use of the Existing System, and the action alternatives, including the No Action Alternative.
- Appendix H-8 presents average annual net evaporation for several of Denver Water's reservoirs for Current Conditions (2006), Full Use of the Existing System, and the action alternatives, including the No Action Alternative.
- Appendix H-9 presents flow duration curves, bedload capacity and supply, and effective discharge graphs.
- Appendix H-10 presents sediment transport capacity curves.
- Appendix H-11 includes a groundwater comment letter from the EPA and the U.S. Army Corps of Engineer's response.
- Appendix H-12 presents native flow depletions at Denver Water's diversions in the Fraser and Williams Fork river basins and native flow increases at the Vasquez Tunnel, Moffat Tunnel, and Roberts Tunnel outfalls for average, dry and wet conditions for Current Conditions (2006), Full Use of the Existing System, and the action alternatives, including the No Action Alternative.
- Appendix H-13 presents shortages for Grand County and Summit County water providers under Full Use of the Existing System.
- Appendix H-14 presents changes in the timing, magnitude and duration of peak flow for Current Conditions (2006), Full Use of the Existing System, and the Proposed Action (Alternative 1a).
- Appendix H-15 presents changes in the frequency and duration of dry year conditions for Current Conditions (2006), Full Use of the Existing System, and the action alternatives, including the No Action Alternative.

- Appendix H-16 presents maps of river basins in the study area that show locations where historic aerial photos were analyzed and stream segments where measurements of channel sinuosity and width were made.
- Appendix H-17 presents data summarizing measurements of channel sinuosity and channel width for stream segments analyzed using historic aerial photos.
- Appendix H-18 presents comparisons of historic aerial photos that were taken of locations in the Fraser River Basin in the 1930s when the Moffat Collection System was constructed with more recent photos taken in 1989, 1990, and 2010.
- Appendix H-19 presents graphs showing the chronological relationship between gage height and flows for several U.S. Geological Survey (USGS) gages in the Fraser and Williams Fork river basins and along the Colorado River.
- Appendix H-20 presents flood frequency curves at each Representative Reach for Current Conditions (2006), Full Use of the Existing System, the Proposed Action (Alternative 1a), Alternative 8a, and the No Action Alternative.
- Appendix H-21 presents figures showing sediment transport capacity at each Representative Reach for various flows and particle sizes using both the Parker equation and the Wilcock and Crowe equations.
- Appendix H-22 presents an overview of the operations of the Environmental Pool (for mitigation purposes) at Gross Reservoir, as evaluated by the Corps.

Hydrologic data presented in the appendices often consists of average monthly values for average, wet, and dry conditions. For each alternative, average values are the average of monthly data for the 45-year study period (1947 through 1991). In addition, dry and wet year values are presented, which are defined as the average of the five wettest and five driest years in the study period (each representing about 10 percent [%] of the period of record). On the West Slope, the five driest years were 1954, 1955, 1963, 1977, and 1981 and the five wettest years were 1952, 1962, 1983, 1984, and 1986, based on estimated natural flows at the USGS gage, Colorado River near Kremmling (Kremmling gage). Natural flows are defined as gaged flows plus adjustments for reservoir releases and filling, diversions, gaged inflows, trans-basin imports, and irrigation or other returns to the river. It reflects the hydrology that existed prior to the development of water supply systems, or the hydrology that would exist if the impacts of water diversions, reservoirs, and return flows were removed. On the East Slope, the five driest years were 1950, 1954, 1963, 1977, and 1981 and the five wettest years were 1949, 1970, 1973, 1983, and 1984, based on estimated natural flows at the USGS gage, South Platte River at South Platte. Natural flows at other gages in the study area were also reviewed to confirm the selection of the five driest and wettest years.

Use of Daily and Monthly PACSM Data for Resource Evaluations

PACSM uses a daily time-step, therefore, daily hydrologic output was generated for each model scenario evaluated. A combination of daily and monthly hydrologic data was used for flow-related resource evaluations. A description of daily and monthly data used for flow-related resources is provided below.

- The surface water evaluation used a combination of daily and monthly hydrologic data. Daily data were used to generate average monthly summaries of flows, diversions, reservoir outflow, end-of-months contents, surface elevations and surface areas for average, dry, and wet conditions. These monthly summaries were relied on to generally characterize hydrologic changes associated with the alternatives. Daily data were used to generate flow duration curves and daily hydrographs and determine the frequency, magnitude, and timing of daily flow changes. Daily data were used in resource assessments where the magnitude or value of the resource is especially sensitive to daily hydrologic changes and where the use of average, wet, and dry monthly and annual values would mask the severity of the effects on those resources. Daily data was utilized to evaluate effects on several resources, including surface water, aquatic resources, stream morphology, recreation, floodplains, riparian and wetlands areas, wildlife and special status species, and water quality.
- The stream morphology analysis relied entirely on daily flow data. Flood frequency analyses, hydraulic modeling, sediment transport capacity modeling, and effective discharge calculations all relied on daily flow data.
- The floodplain analysis relied entirely on daily flow data. Daily flow data were used to conduct flood frequency analyses.
- The recreation analysis relied on daily flow data to determine the change in number of days within flow intervals determined optimal for boating.
- The aquatic biological resources analysis relied on daily data to simulate fish habitat and evaluate the impacts on fish populations using the Instream Flow Incremental Methodology.
- The evaluation of riparian and wetlands areas relied entirely on daily flow data to determine changes in river stage and inundated area along river segments for various flood events.
- Evaluation of wildlife and special status species relied on the results of the riparian analysis and on monthly hydrologic data.
- The water quality analysis relied on monthly flow data to highlight stream segments for analysis of potential changes. For locations in the Fraser River Basin warranting additional evaluation of the effects on stream temperature, daily PACSM output was utilized to characterize potential impacts.

Methodology for Analysis of Impacts on Surface Water

Impacts on surface water hydrology are described for each affected river basin. Average monthly and annual summaries of flows, diversions, reservoir outflow, end-of-months contents, surface elevations and surface areas for average, dry and wet conditions were relied on to generally characterize surface water changes associated with the alternatives. Flow duration curves and daily hydrographs were used to determine the frequency and magnitude of daily flow changes. The Nature Conservancy's Indicators of Hydrologic Alteration (IHA) was also used to evaluate changes in the magnitude, timing, frequency, and duration of four different types of Environmental Flow Components (EFCs): low flows, high flow pulses, small floods, and large floods.

Impacts on floodplains are also described for each affected river basin. Impacts on floodplains were not directly evaluated using hydraulic modeling. Rather, the annual flood series (based on daily flow output generated by PACSM) were reviewed. Probability plotting analyses were conducted and used as the basis for evaluating peak flow frequency. Peak flows for the 45-year study period were ranked and assigned Weibull plotting positions, from which recurrence intervals were estimated. Changes to floodplain extents were inferred from this information, and are summarized qualitatively. This approach was deemed appropriate because the Moffat Project would generally reduce flows during high flow periods on the West Slope. As a result, the potential for creating additional flood hazard is considered low.

4.6.1.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Under the Proposed Action with RFFAs, a 77,000 AF enlargement would be constructed at Gross Reservoir. Of the 77,000 AF enlargement, 72,000 AF would be utilized to provide new firm yield to Denver Water's system and 5,000 AF would be an Environmental Pool for mitigation. The environmental effects discussed for surface water correspond with the 72,000 AF enlargement whereas the operations and effects associated with the 5,000 AF Environmental Pool are discussed in Appendices H-22 and M-2. Using existing collection infrastructure, primarily average to wet-year Fraser River, Williams Fork River, and South Boulder Creek water would be diverted and delivered via the Moffat Tunnel and South Boulder Creek to the existing Gross Reservoir. Existing facilities, including the South Boulder Diversion Canal and Conduits 16 and 22, would be used to deliver water from the enlarged Gross Reservoir to the Moffat Water Treatment Plant (WTP). In general, the majority of "new" water diverted to Gross Reservoir would be kept in storage until a dry year or sequence of below average years occurs. This scenario also includes other RFFAs that are anticipated to occur by 2032.

4.6.1.1.1 Reservoir Evaporation and Fluctuation

Reservoir evaporation, contents, and elevations under the Proposed Action with RFFAs were compared to the Current Conditions (2006) scenario to identify differences between the two scenarios. The following reservoirs were evaluated:

- Williams Fork Reservoir
- Dillon Reservoir
- Wolford Mountain Reservoir
- Gross Reservoir
- Antero Reservoir
- Eleven Mile Canyon Reservoir
- Cheesman Reservoir
- Strontia Springs
- Chatfield Reservoir

Williams Fork Reservoir

Williams Fork Reservoir contents would generally be higher under the Proposed Action with RFFAs than under Current Conditions (2006), the net result of several changes that are mutually offsetting. Termination of Big Lake Ditch diversions above the reservoir and discontinuation of 10,825 Water releases from Williams Fork Reservoir tend to result in more water in storage. Increased Gumlick Tunnel diversions and greater releases for substitution and exchange, in the absence of the effects already mentioned, would result in less water in storage. The dynamics that would reduce water in storage will occur due to growth in Denver Water's demand both before and after implementation of the Proposed Action.

Average differences in end-of-month contents would range from approximately 500 to 4,200 AF, which translates to greater average monthly water elevations of 1 to 4 feet. The largest increase in average monthly end-of-month contents under the Proposed Action with RFFAs would be 4,200 AF or 6% in September. In dry years, the largest increase in average monthly end-of-month contents would be 7,700 AF or 11%, and in wet years it would be 4,600 AF (Table H-1.1). The monthly average end-of-month water elevation would increase by a maximum of 4 feet in average years and 6 feet in wet years as well as dry years (Table H-1.2). The maximum increase in water elevation (averaged over the month) between the Proposed Action with RFFAs and Current Conditions (2006), for any month over the 45-year study period, would be 44 feet; the maximum decrease in water elevation would be 36 feet. The average annual evaporative loss would be 3,331 AF compared to 3,227 AF under Current Conditions (2006), as shown in Table H-8.1.

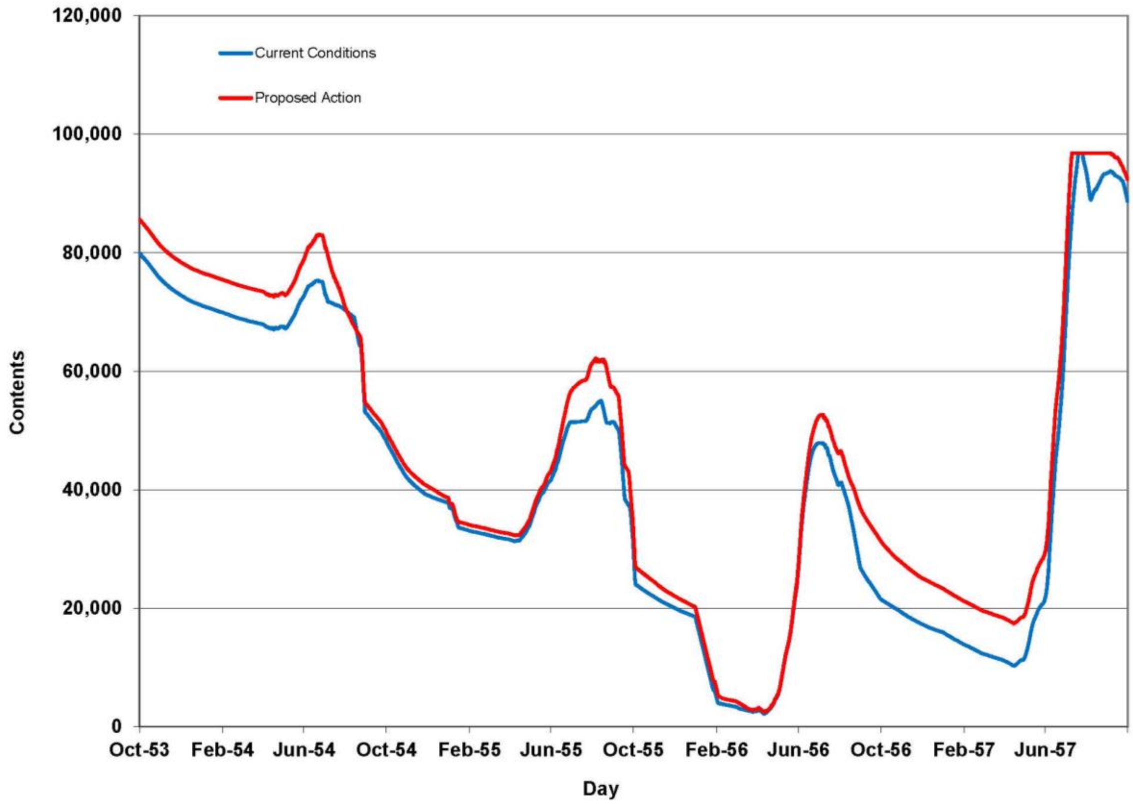
In dry years, Williams Fork Reservoir would begin the water year with approximately 5,400 AF more in storage under the Proposed Action with RFFAs compared to Current Conditions (2006), due primarily to the greater water supply available once the Big Lake Ditch diversions cease. This difference in content is more or less maintained until July. In July and August, the increased substitution and exchange releases under the Proposed Action would reduce the gap without closing it completely. By the end of the water year, reservoir contents would be approximately 3,000 AF greater under the Proposed Action with RFFAs than Current Conditions (2006).

Figure 4.6.1-1 demonstrates how reservoir contents at Williams Fork Reservoir can vary substantially in dry years depending on the severity and length of the drought, hydrologic conditions in the years preceding the drought, and substitution releases for Denver Water. Figure 4.6.1-1 shows the drawdown that would occur at Williams Fork Reservoir through the critical period (1953 through 1957) under both Current Conditions (2006) and the Proposed Action with RFFAs.

In wet years, Williams Fork Reservoir's contents under the Proposed Action with RFFAs would be greater than contents under Current Conditions (2006) by 4,600 AF at the end of October. Reservoir contents for the two scenarios would converge over the next seven months as the reservoir operates to reach similar targets by end of April. Under both scenarios, Williams Fork Reservoir fills at similar rates during runoff reaching fill by the end of July. Through the next two months, reservoir contents would remain very similar, specifically, about 500 AF higher under the Proposed Action with RFFAs compared to Current Conditions (2006). The difference is the net result of inflow differences,

differences in releases of 10,825 Water (none under the Proposed Action with RFFAs), and greater exchange releases to Dillon Reservoir under the Proposed Action with RFFAs, relative to Current Conditions (2006).

Figure 4.6.1-1
Comparison of Williams Fork Reservoir Contents During the Critical Period



Dillon Reservoir

Differences in Dillon Reservoir contents under Current Conditions (2006) compared to Proposed Action with RFFAs are due to increases in Denver Water's exports of Blue River water, primarily prior to implementation of the Proposed Action but also following it. Increases in local use of Blue River water above Dillon Reservoir also contribute to differences in inflow to Dillon. Finally, a seasonal shift in Roberts Tunnel diversions is responsible for a difference in the average rate of change in reservoir levels. Under Current Conditions (2006), Denver Water shuts down the Moffat WTP from October through March and winter demand is met entirely by Foothills and Marston WTPs. Under the Proposed Action with RFFAs, the Moffat WTP would operate at a minimum of 30 mgd through the winter, which shifts a significant portion of the winter treatment load away from Foothills and Marston WTPs to the Moffat WTP. Since Denver Water's South System primarily uses water diverted from the Blue River rather than South Platte River water in the winter, the shift would affect Roberts Tunnel diversions and Dillon Reservoir levels.

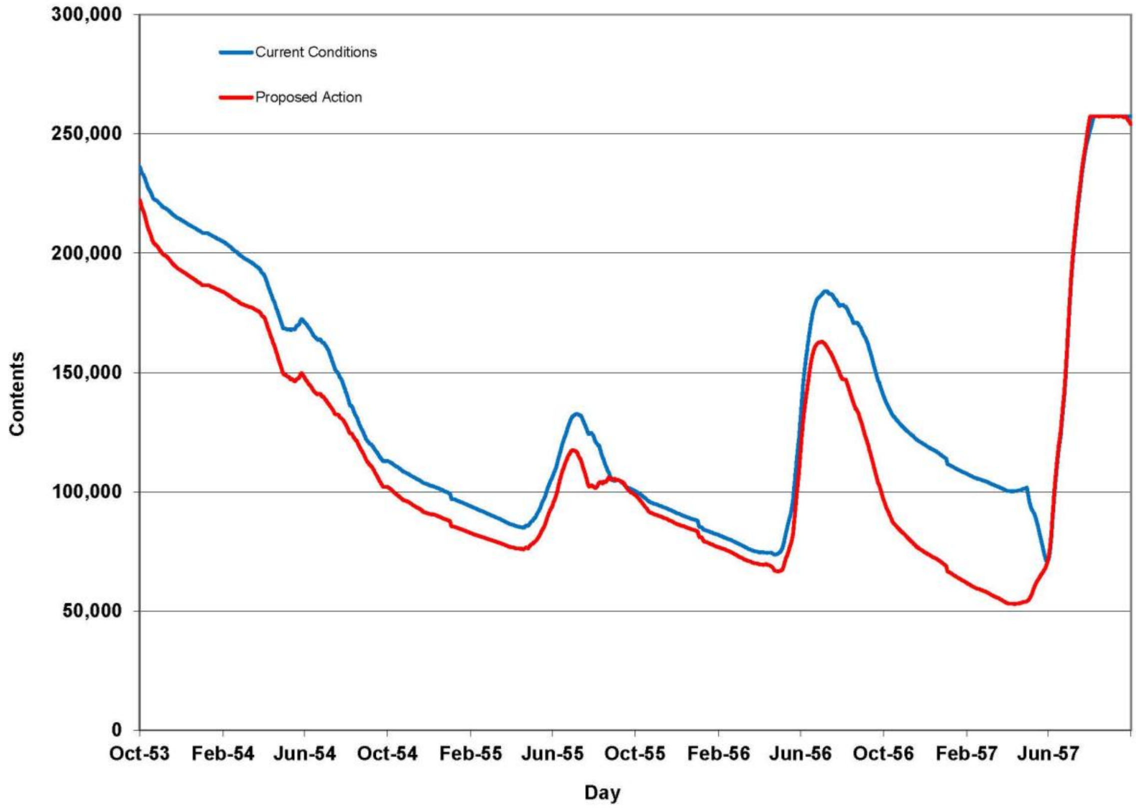
From November to April, Roberts Tunnel diversions would be 4,800 AF less on average under the Proposed Action with RFFAs. From May through October diversions would increase by 36,900 AF on average, for a net average increase in Roberts Tunnel diversions of 32,100 AF annually. Dillon Reservoir would enter the runoff season with 22,600 AF less in storage on average at the end of April. During May and June, Dillon Reservoir contents would be lower but the difference in average contents would decline by end of June because Dillon Reservoir still achieves fill in wet years. By the end of June, average Dillon Reservoir contents would be 11,100 AF lower under the Proposed Action with RFFAs. From July through October, the difference would widen primarily because of additional Roberts Tunnel diversions, resulting in a difference of 27,900 AF in October. Through the winter, Roberts Tunnel would deliver less water than under Current Conditions (2006), and as a result, the difference in April content as mentioned above is 22,600 AF.

The largest monthly difference in average end-of-month contents would occur in October, when Dillon Reservoir contents would be 27,900 AF or 13% less under the Proposed Action with RFFAs (Table H-1.4). The corresponding difference in reservoir elevation would be 11 feet (Table H-1.5). The maximum increase in water elevation (averaged over the month) compared to Current Conditions (2006), for any month over the 45-year study period, is 13 feet; the maximum decrease in water elevation is 38 feet. The average annual evaporative loss would be 5,368 AF compared to 5,847 AF under Current Conditions (2006), as shown in Table H-8.1.

In dry years, the difference in average end-of-month contents for Dillon Reservoir would range from 27,400 AF in March to 41,300 AF in July. At the end of October, storage contents would be 28,600 AF less compared to Current Conditions (2006). The winter reduction in Roberts Tunnel diversions is less pronounced in dry years than in wet and average years, such that the difference in contents by the end of March is 27,400 AF. Roberts Tunnel diversions in April are similar in the two scenarios, as are bypasses for maintaining minimum flows in the Blue River below Dillon Reservoir, but during May, June, and July, Roberts Tunnel diverts approximately 30 to 50% more under the Proposed Action with RFFAs than under Current Conditions (2006). In dry years, Dillon Reservoir contents decrease from the beginning of runoff to the end of the July. Dillon Reservoir contents would decrease about 15,000 AF over the same period under Current Conditions (2006). Thus by the end of July, the difference in contents would be 41,300 AF as mentioned above. The difference becomes smaller by the end of August. Roberts Tunnel diversions in August are similar in the two scenarios, but under Current Conditions (2006), Dillon Reservoir must bypass physically available water because there would be no exchange water remaining in Williams Fork Reservoir. Under the Proposed Action with RFFAs, Williams Fork Reservoir has more water available to it; Dillon Reservoir is able to capture the water that is physically available in August by making releases for exchange from Williams Fork Reservoir. In September, Roberts Tunnel diversions are somewhat higher under the Proposed Action with RFFAs than Current Conditions (2006), which is reflected in a commensurate increase in the difference in reservoir contents between the two scenarios by the end of the water year.

Figure 4.6.1-2 demonstrates how reservoir contents at Dillon Reservoir can vary substantially in dry years depending on the severity and length of the drought, and hydrologic conditions in the years preceding the drought. Figure 4.6.1-2 shows the drawdown that would occur at Dillon Reservoir through the critical period (1953 through 1957) under both Current Conditions (2006) and the Proposed Action with RFFAs.

Figure 4.6.1-2
Comparison of Dillon Reservoir Contents During the Critical Period



In wet years, Dillon Reservoir contents are less on average under the Proposed Action with RFFAs in every month except for May, when pre-emptive releases would be made under Current Conditions (2006) to draw down the reservoir in anticipation of runoff. The number of days that Dillon Reservoir is full and spilling would be reduced by between 30 and 40%. This change is manifest under Full Use of the Existing System and slightly mitigated under the Proposed Action with RFFAs. At the beginning of the water year, Dillon Reservoir would be close to full under Current Conditions (2006), while under the Proposed Action with RFFAs, Dillon Reservoir would be 14,100 AF lower. Through winter and early spring, releases would be made under Current Conditions (2006) to gradually lower the reservoir whereas under the Proposed Action with RFFAs releases more or less maintain the reservoir level. Water would be spilled under both scenarios such that fill is achieved by the end of July, but the timing differs. Under Current Conditions (2006), water would be released pre-emptively, therefore reservoir contents under Current Conditions (2006) are lower than under the Proposed Action with RFFAs for a short time, but "catch up" quickly. In August and September, greater diversions through Roberts Tunnel account for lower contents under the Proposed Action with RFFAs than under Current Conditions (2006). In wet years, the largest monthly difference in contents would occur in October, when Dillon Reservoir content would be 17,700 AF less on average under the Proposed Action with RFFAs (Table H-1.4). The corresponding difference in water elevation would be 6 feet on average (Table H-1.5).

Wolford Mountain Reservoir

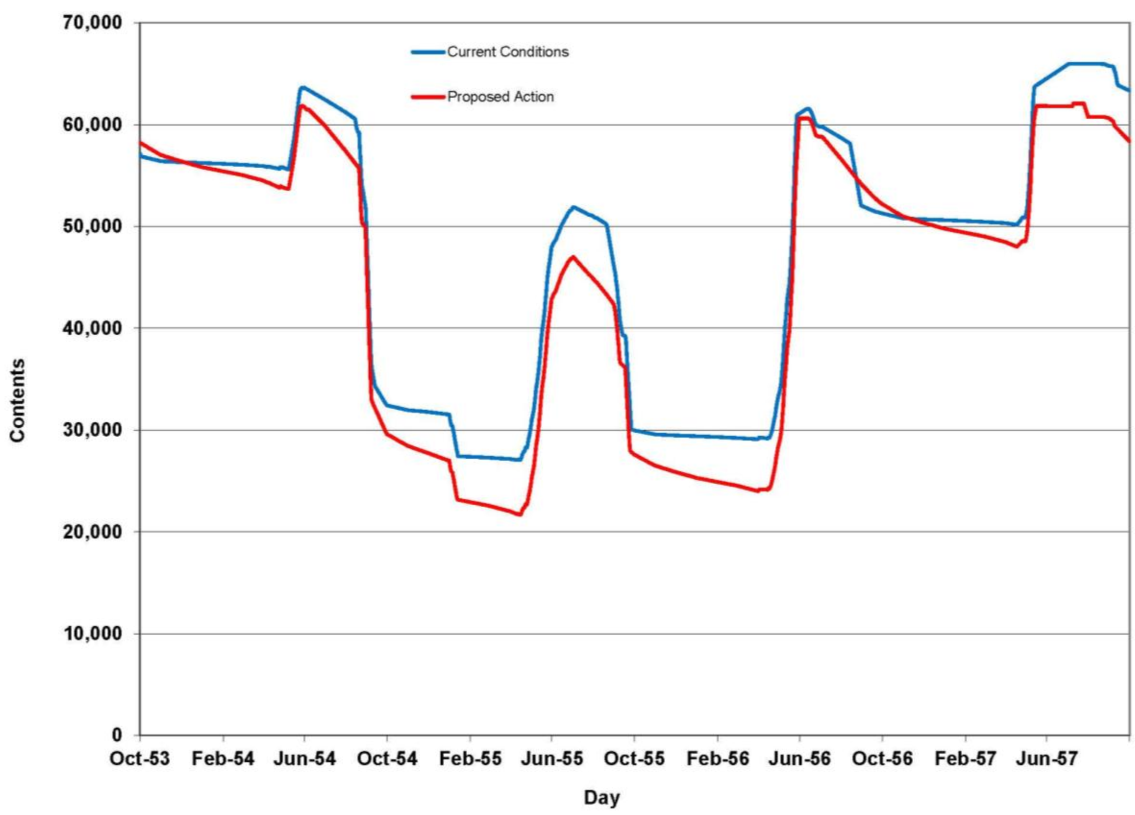
Differences in water levels in Wolford Mountain Reservoir, for the Proposed Action with RFFAs relative to Current Conditions (2006), are due strictly to changes in reservoir operations, as there is no difference in inflow to the reservoir. The two scenarios feature three significant differences in Wolford Mountain Reservoir operations:

1. Discontinuation of 10,825 Water releases – under Current Conditions (2006), 5,412 AF is generally released in late summer and fall, to meet endangered fish flow needs in the 15-Mile Reach. Under the Proposed Action with RFFAs, this operation would be moved to Granby and Ruedi reservoirs, which, in the absence of other changes, would result in more water in the reservoir in late summer.
2. West Slope contracts – Under the Proposed Action with RFFAs, it is anticipated that contracts with West Slope entities would increase substantially. These contracts would result in releases of an average of 4,700 AF/yr. This change, in the absence of other changes, would result in less water in the reservoir.
3. Increased substitution releases – to support additional Denver Water and Colorado Springs diversions from the Blue River, both before and after implementation of the Proposed Action, more water would be released from Denver's pool under the Proposed Action with RFFAs, as compared with Current Conditions (2006). In the absence of other changes, these releases, typically made in late summer and early fall, would result in less water in the reservoir.

The net result of these actions would be that average end-of-month contents under the Proposed Action with RFFAs would be less than average end-of-month contents under Current Conditions (2006) for every month of the year. At the beginning of the water year, contents would be 3,200 AF lower under the Proposed Action with RFFAs. The difference would generally increase through March due primarily to West Slope contract releases, and to a lesser degree, substitution releases. At the end of March, the difference would be 5,300 AF. Contract releases persist through May under the Proposed Action with RFFAs, but that effect is more than offset during runoff as more water is stored on average under the Proposed Action with RFFAs than under Current Conditions (2006). By end of June, the difference in contents is 3,400 AF on average. During July, August, and September, this difference is more or less maintained as reservoir contents reflect increased substitution and contract deliveries, offset by the termination of 10,825 Water releases. The water year ends with a difference of 3,200 AF. Differences in contents range from 3,000 AF in August to 5,300 AF in March. Differences in water elevations at Wolford Mountain Reservoir range from 2 feet to 5 feet (Table H-1.8). The maximum increase in reservoir elevation (averaged over the month) between the Proposed Action with RFFAs and Current Conditions (2006), for any month over the 45-year study period, is 1.5 feet; the maximum decrease in reservoir elevation is 37 feet. The average annual evaporative loss would be 2,570 AF compared to 2,701 AF under Current Conditions (2006), as shown in Table H-8.1.

In dry years, outflow from Wolford Mountain Reservoir would be greater under the Proposed Action with RFFAs than Current Conditions (2006) in every month of the year except August. From October through July, increased contract releases, coinciding with limited inflow during runoff months, cause the difference in reservoir content to increase from 900 AF to 5,000 AF. In August, the trend reverses due to 10,825 Water releases under Current Conditions (2006), which are absent from the Proposed Action with RFFAs. The water year ends with a difference in reservoir contents of 3,000 AF. The greatest difference in average end-of-month contents is 5,000 AF in dry years, which corresponds to a difference in water elevation of 4 feet. Figure 4.6.1-3 demonstrates how reservoir contents at Wolford Mountain Reservoir can vary substantially in dry years depending on the severity and length of the drought, hydrologic conditions in the years preceding the drought, and substitution releases for Denver Water and Colorado Springs. Figure 4.6.1-3 shows the drawdown that would occur at Wolford Mountain Reservoir through the critical period (1953 through 1957) under both Current Conditions (2006) and the Proposed Action with RFFAs.

Figure 4.6.1-3
Comparison of Wolford Mountain Reservoir Contents During the Critical Period



In wet years, Wolford Mountain Reservoir contents are always lower under the Proposed Action with RFFAs than Current Conditions (2006). The difference increases through late fall and winter as more water would be released under the Proposed Action with RFFAs to satisfy West Slope contracts. The greatest difference (approximately 5,200 AF) occurs at the end of March. During runoff, the reservoir spills less and stores more under the Proposed Action with RFFAs, so that it is within several hundred acre-feet of contents under Current Conditions (2006) in May and June. In August and September the difference in contents increases again such that the water year ends with a difference of 2,400 AF. The greatest difference in average end-of-month contents is 5,200 AF in wet years, which corresponds to a difference in water elevation of 5 feet.

Gross Reservoir

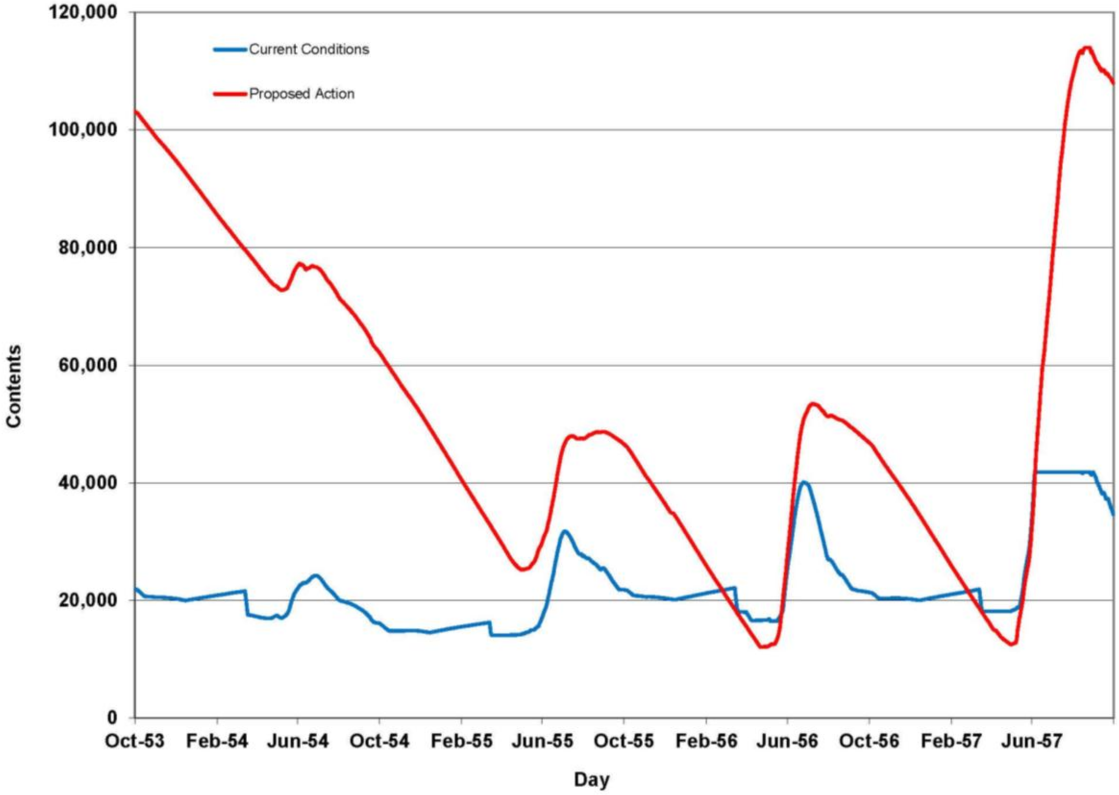
Under the Proposed Action with RFFAs and the Environmental Pool, Gross Reservoir's volume would increase by 77,000 AF to 118,811 AF, which is more than twice its current volume. The surface water area at normal high water would change by a factor of two, from approximately 418 acres to 824 acres and the water level would increase by 124 feet. Of the 77,000 AF enlargement, 72,000 AF would be utilized to provide new firm yield to Denver Water's system and 5,000 AF would be an Environmental Pool for mitigation. The effects discussed in this section correspond with the 72,000 AF enlargement. The environmental effects of a 77,000 AF expansion are expected to be similar to the 72,000 AF expansion. Additional discussion specific to the operations and effects associated with the 5,000 AF Environmental Pool is provided in Appendices H-22 and M-2.

From April through October, the annual pattern of fluctuation in water level and content would be similar to that under Current Conditions (2006): the reservoir would be at its lowest at the end of April, reach its highest level in June or July, and would be drawn down through the fall. Under Current Conditions (2006), the Moffat WTP does not operate in the winter months; therefore, contents increase on average from November through February. However, under the Proposed Action with RFFAs, Gross Reservoir contents would drop steadily by 4,000 to 5,000 AF per month during these months because the Moffat WTP would be operating at a minimum of 30 mgd plus there would be releases for raw water contracts. Differences in reservoir contents under the Proposed Action with RFFAs are greatest in wet years following a drought, when the enlarged capacity of Gross Reservoir would fill.

Average monthly contents would be greatest at the end of July at 102,500 AF and lowest at the end of April at 69,500 AF (Table H-1.10). In wet years, monthly contents during summer months would be higher than average. In dry years, monthly contents during summer months would be lower than average because the reservoir would be drawn on more heavily during a drought. Figure 4.6.1-4 demonstrates how Gross Reservoir would be used through the critical period (1953 through 1957) under both Current Conditions (2006) and the Proposed Action with RFFAs.

The maximum increase in water elevation (averaged over the month) compared to Current Conditions (2006), for any month over the 45-year study period, is 163 feet; the maximum decrease in reservoir elevation is 20 feet. The average annual evaporative loss would be 991 AF compared to 452 AF under Current Conditions (2006), as shown in Table H-8.1.

Figure 4.6.1-4
Comparison of Gross Reservoir Contents During the Critical Period



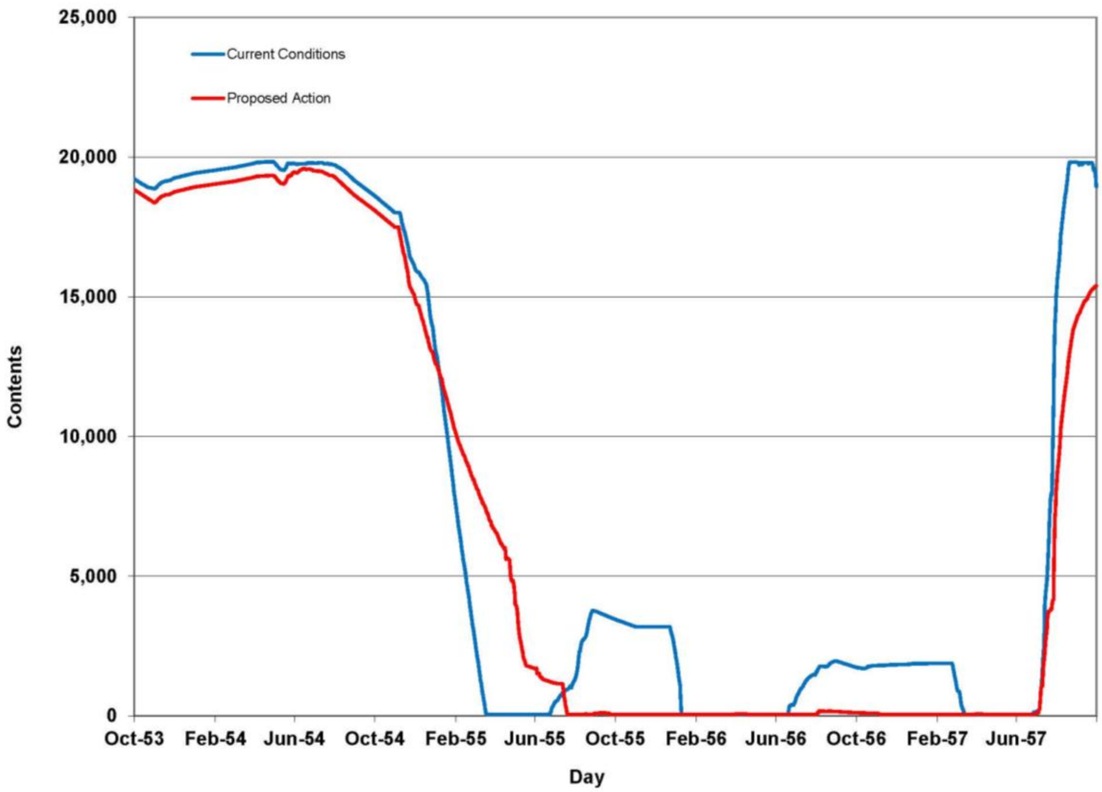
Antero Reservoir

Under the Proposed Action with RFFAs, there would be little to no difference in Antero Reservoir contents in many months, as compared to Current Conditions (2006). Antero Reservoir contents would be lower by 400 to 800 AF, on average (Table H-1.13). The largest decrease in average monthly end-of-month contents would be 820 AF in December and 700 AF in September in dry years. There would be little to no change in contents in wet years.

In general, Denver Water uses Antero Reservoir in a prolonged drought. Therefore, during the majority of the study period, reservoir contents are similar to Current Conditions (2006) because Antero Reservoir would be maintained full. Monthly average differences reflect differences in the timing of isolated drawdowns and subsequent refills that occur during droughts. The differences are manifest in years that are neither wet nor dry, because Antero Reservoir is not used until water levels in Cheesman Reservoir are substantially lowered due to releases during a drought. Generally, it is after the first year of a dry period that drawdown and differences in water levels would occur at Antero Reservoir. As a result, the drawdowns that occur during a drought are not reflected well in the dry year average end-of-month contents shown in Table H-1.13 because the 5 driest years of the study period do not necessarily coincide with years that Antero Reservoir would be drawn down.

Figure 4.6.1-5 shows the drawdown that would occur at Antero Reservoir during the critical period from 1953 through 1957. Under both Current Conditions (2006) and the Proposed Action with RFFAs, Antero Reservoir would remain full in 1954, which is the first year of the drought. In that year, Denver Water would rely on water supplies in their other reservoirs such as Dillon Reservoir, which is substantially drawn down in the first year of that drought. Antero Reservoir is not drawn down until 1955, which is the second year of the drought. The reservoir remains empty under the Proposed Action with RFFAs until it starts to refill in the summer of 1957. Antero Reservoir is partially drawn down three more times during the study period.

Figure 4.6.1-5
Comparison of Antero Reservoir Contents During the Critical Period



The maximum monthly average end-of-month water elevation change would be a decrease of less than 1 foot in average and dry years (Table H-1.14). The maximum increase in water elevation (averaged over the month) compared to Current Conditions (2006), for any month over the 45-year study period, is 9 feet; the maximum decrease in water elevation is also 9 feet. The average annual evaporative loss would be 3,602 AF compared to 3,671 AF under Current Conditions (2006), as shown in Table H-8.1.

Eleven Mile Canyon Reservoir

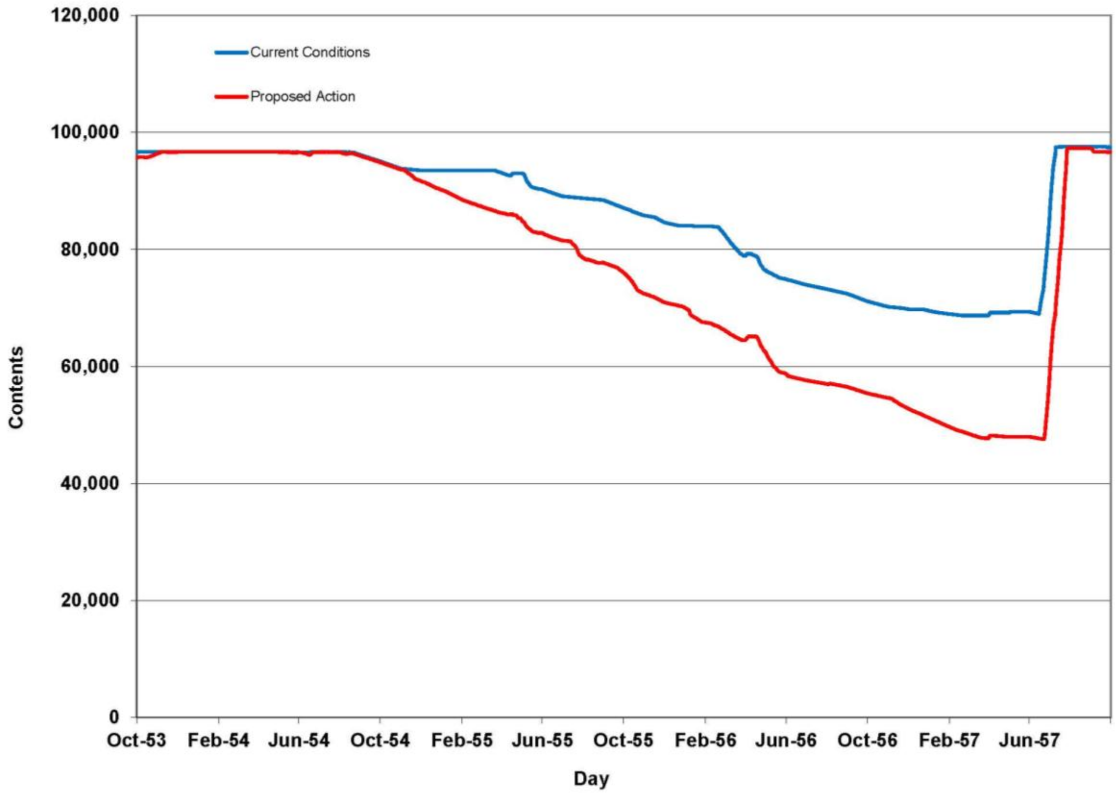
Changes in Eleven Mile Canyon Reservoir contents under the Proposed Action with RFFAs would be due to changes in releases to meet a higher demand. Contents of Eleven Mile Canyon Reservoir would be 2,300 AF lower on average, compared to Current Conditions

(2006), as shown in Table H-1.16. The largest decrease in average monthly end-of-month contents would be 2,900 AF in average years, and 1,400 AF in dry years (Table H-1.16). Reservoir contents are very similar in wet years.

Like Antero Reservoir, Eleven Mile Canyon Reservoir is drawn down in multiyear, prolonged droughts. Therefore, reservoir contents are similar to Current Conditions (2006) during the majority of the study period, because Eleven Mile Canyon Reservoir would be maintained full most of the time. Monthly average differences in contents reflect differences in the timing of isolated drawdowns and subsequent refills that occur during droughts. The differences are manifest in years that are neither wet nor dry, because Eleven Mile Canyon Reservoir is not used until water levels in Cheesman Reservoir are substantially lower due to releases during a drought. The biggest differences occur late in dry years and in years that follow a dry year. As a result, drawdowns that occur during a drought are not reflected well in the dry year average end-of-month contents shown in Table H-1.16 because the 5 driest years of the study period do not necessarily coincide with the years that Eleven Mile Canyon Reservoir would be drawn down. Figure 4.6.1-6 shows the drawdown that would occur at Eleven Mile Canyon Reservoir during the critical period from 1953 through 1957. During the critical period, Eleven Mile Canyon Reservoir remains close to full in 1954, which is the first year of the drought. In that year, Denver Water would rely on water supplies in their other reservoirs such as Dillon Reservoir, which is substantially drawn down in the first year of that drought. Eleven Mile Canyon Reservoir is partially drawdown starting in the winter of 1954 through the spring of 1957. Contents are approximately 20,000 AF less under the Proposed Action with RFFAs than Current Conditions (2006) in the spring of 1957 prior to runoff. The reservoir then refills in the summer of 1957 under both the Proposed Action with RFFAs and Current Conditions (2006).

The maximum monthly average end-of-month water elevation change would be a decrease of approximately 1.2 feet in average years and a decrease of about zero feet in dry years (Table H-1.17). The maximum increase in water elevation (averaged over the month) compared to Current Conditions (2006), for any month over the 45-year study period, is 0.2 feet; the maximum decrease in water elevation is 12.9 feet. The average annual evaporative loss would be 5,856 AF compared to 5,950 AF under Current Conditions (2006), as shown in Table H-8.1.

Figure 4.6.1-6
Comparison of Eleven Mile Canyon Reservoir Contents During the Critical Period



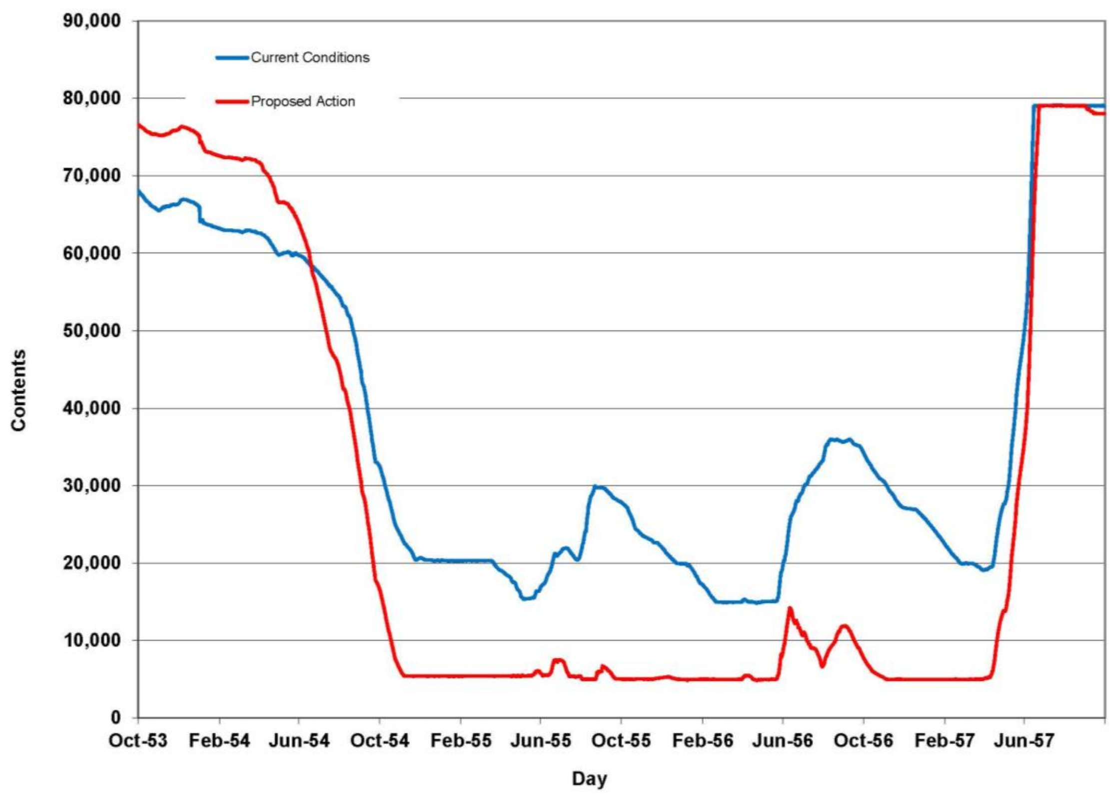
Cheesman Reservoir

The shift in treatment plant operations during the winter, higher Denver Water demand both prior to and after implementation of the Proposed Action with RFFAs, and greater amounts of reusable effluent exchanged to Cheesman Reservoir would affect Cheesman Reservoir contents. At the end of October, Cheesman Reservoir contents would be about 100 AF lower than under Current Conditions (2006). Because of Denver Water's demand, the difference grows by the end of March, but the difference is mitigated by the seasonal shift in treatment away from Foothills and Marston WTPs to the Moffat WTP. At the end of March, the difference is 700 AF. During runoff and the first half of summer, Cheesman Reservoir would be used more heavily because Denver Water's demand would be higher under the Proposed Action with RFFAs. But in August, September, and October, the difference becomes smaller, as Denver Water's use of Blue River water also increases. The reusable effluent generated by use of Blue River water is exchanged to Cheesman Reservoir which means more water is stored during these months compared to Current Conditions (2006).

The largest change in average monthly end-of-month contents would be a 2,600 AF decrease in average years, a 6,700 AF increase in dry years, and a 2,700 AF increase in wet years (Table H-1.19). The maximum average end-of-month water elevation change would be a decrease of 6 feet. The maximum average end-of-month difference in dry years and wet years, would be an increase of 8 feet and 3 feet, respectively (Table H-1.20). The maximum increase in water elevation (averaged over the month) compared to Current Conditions (2006), for any month over the 45-year study period, is 20 feet; the maximum decrease in water elevation is 88 feet. The average annual evaporative loss would be 1,058 AF compared to 1,081 AF under Current Conditions (2006), as shown in Table H-8.1.

In dry years, differences are partly related to conditions prior to the five designated dry years. End of September contents for the water years preceding the designated dry years would be approximately 5,900 AF higher than under Current Conditions (2006). As winter progresses, this difference remains more or less the same until March, with the seasonal shift in WTP operations offsetting changes due to increased demand. From April through September, Denver draws more water from Cheesman Reservoir than under Current Conditions (2006), therefore, contents drop more sharply under the Proposed Action with RFFAs. The difference becomes less each month until in September, reservoir content are 1,900 AF lower than under Current Conditions (2006). Figure 4.6.1-7 shows the drawdown that would occur at Cheesman Reservoir during the critical period from 1953 through 1957. During the critical period, Cheesman Reservoir is substantially drawdown during 1954, which is the first year of the drought, under both Current Conditions (2006) and the Proposed Action with RFFAs. Reservoir contents remain low under both scenarios until the spring of 1957. During the majority of the critical period, reservoir contents are approximately 15,000 AF lower. The reservoir then refills in the summer of 1957 under both the Proposed Action with RFFAs and Current Conditions (2006).

Figure 4.6.1-7
Comparison of Cheesman Reservoir Contents During the Critical Period



In wet years, differences are also partly related to conditions prior to the five designated wet years. The water year begins with more water in Cheesman Reservoir, and this positive difference persists until fill is achieved at the end of June in both scenarios. Contents are higher than under Current Conditions (2006) at the end of the water year, due to the combined influences of increased demand, exchanges, and operations at Eleven Mile Reservoir.

Strontia Springs Reservoir

Strontia Springs Reservoir is a regulating reservoir and the forebay for Conduit 26, which flows to the Foothills WTP. Water levels fluctuate daily, such that end-of-month contents are variable and may not represent conditions during the rest of the month.

Under the Proposed Action with RFFAs, less water would be delivered to Strontia Springs Reservoir from Cheesman Reservoir and the Roberts Tunnel in the winter, due to the addition of winter treatment capacity at the Moffat WTP. More Blue River water is delivered to Strontia Springs Reservoir in summer months, which means that Strontia Springs Reservoir can potentially store more water by exchange at times. However, these differences in inflow are offset by the effects of Denver Water's increase in demand. As a result, reservoir levels are lower compared to Current Conditions (2006). Contents are similar from October through December, but from January through September, contents are lower by several hundred acre-feet. The maximum decrease in monthly average contents is approximately 760 AF in August. The corresponding difference in water elevation is 11 feet.

The description above is applicable to both dry years and wet years, except that the maximum decrease in monthly average contents is 990 AF in dry years, for a water elevation difference of 14 feet. Effects are less in wet years, with the maximum monthly average decrease in contents being 630 AF for a water elevation difference of 8 feet. The maximum increase in water elevation (averaged over the month) compared to Current Conditions (2006), for any month over the 45-year study period, is 22 feet; the maximum decrease in water elevation is 72 feet.

Chatfield Reservoir

Chatfield Reservoir contents are generally the same as or greater under the Proposed Action with RFFAs than under Current Conditions (2006). With Denver Water importing more Blue River water to meet increased demand, there are more opportunities to exchange effluent credits upstream to Chatfield Reservoir. Winter drawdowns that approach the bottom of the operating pool are significantly less frequent under the Proposed Action with RFFAs than under Current Conditions (2006).

4.6.1.1.2 River Segments

Fraser River

For the purpose of analyzing changes in surface water hydrology in the Fraser River Basin, modeled diversions and stream flows were evaluated at the locations of interest shown in Table 4.6.1-2. These locations coincide with the primary sections of Denver Water's Moffat Collection System, which include:

- St. Louis Creek
- Vasquez Creek
- Fraser River-Jim Creek
- Ranch Creek Section

Denver Water has 32 primary diversion points in the Fraser River Basin, which are listed in Table 3.1-6. In PACSM, several of the smaller tributaries that Denver Water diverts from are combined and modeled jointly. This approach is reasonable because the tributaries are located in close proximity, diversions are of similar magnitude and timing, and there is little or no gage data that could be used to model them separately. For example, Cub and Buck creeks were modeled jointly. These creeks have no gages, are within one mile of each other, and the elevation, size and aspect of the contributing watersheds to these creeks are similar. Table 4.6.1-2 includes information regarding which tributaries are combined and modeled jointly. In general, Denver Water diverts water from the Fraser and Williams Fork river basins in the following order:

1. Fraser River
2. Vasquez Creek
3. Elk Creek
4. St. Louis Creek
5. Ranch Creek
6. Williams Fork River Collection System
7. Englewood Ranch Creek Diversion
8. Releases from Meadow Creek Reservoir

Table 4.6.1-2
Locations Where Hydrologic Data were Analyzed in the Fraser River Basin

Location Description	PACSM Node #
Moffat Tunnel Diversions	N/A
Fraser River below Denver Water's Diversion	2120
Jim Creek below Denver Water's Diversion	2160
St. Louis Creek below Denver Water's Diversion	2170
St. Louis Tributaries below Denver Water's Diversion[1]	2180
St. Louis Creek Near Fraser Gage	2200
King Creek below Denver Water's Diversion	2220
Vasquez Creek below the Gumlick Tunnel Outfall	2260
Vasquez Creek below Denver Water's Diversion	2280
Elk Creek and Tributaries below Denver Water's Diversion[2]	2300
Little Vasquez Creek below Denver Water's Diversion	2340
Vasquez Creek Gage	2370

Table 4.6.1-2 (continued)
Locations Where Hydrologic Data were Analyzed in the Fraser River Basin

Location Description	PACSM Node #
Cooper Creek below Denver Water's Diversion	2380
Englewood Ranch Gravity System below Denver Water's Diversion[3]	2480
North Fork Ranch Creek and Dribble Creek below Denver Water's Diversion	2490
Main Ranch Creek below Denver Water's Diversion	2500
Middle and South Fork of Ranch Creek below Denver Water's Diversion	2520
Cub and Buck Creek below Denver Water's Diversion	2540
Fraser River Near Winter Park Gage	2580
Fraser River below the Confluence with Vasquez Creek	2600
Fraser River below the Confluence with St. Louis Creek	2700
Fraser River below the Confluence with Crooked Creek	2810
Fraser River at Granby Gage	2900

Notes:
Refer to Figure 3.0-1 for the locations of PACSM nodes.
[1]St. Louis Creek tributaries include West St. Louis, Short, Byers, Iron, East St. Louis, and Fool creeks.
[2]Elk Creek tributaries include West Elk, East Fork Main Elk, West Fork Main Elk, and East Elk creeks.
[3]Englewood Ranch Gravity System includes North Trail, South Trail, Hurd, Hamilton, Cabin, and Little Cabin creeks.
N/A = not applicable
PASCM = Platte and Colorado Simulation Model

Changes in Fraser River flows are directly related to Denver Water's increased demand and the increase in storage capacity at Gross Reservoir, which would enable Denver Water to store more water brought through the Moffat Tunnel. With increased storage capacity on the East Slope, Denver Water would be able to divert water that it is unable to capture without additional storage. Denver Water's average annual demand would increase from 285,000 AF under Current Conditions (2006) to 363,000 AF/yr under the Proposed Action with RFFAs. There would also be changes in flows due to additional municipal diversions, including changes in the timing and quantity of return flows associated with water uses in the Fraser River Basin. The largest growth in water demand in the Fraser River Basin is expected to occur in areas served by the Grand County Water and Sanitation District, the Town of Fraser and Silver Creek Resort.

Bypass Flow Reductions

Under the 1970 Bureau of Sport Fisheries Stipulation and the 1992 Clinton-Fraser Agreement, Denver Water may reduce bypass flows in accordance with the severity of restrictions it places on its customers; however, the agreements do not define set amounts for the bypass flow reductions. To reflect the reduction in minimum bypass flows in PACSM, the bypass flows at four diversions in the Fraser River Basin (Fraser River, Vasquez Creek, St. Louis Creek, and Main Ranch Creek) were reduced by up to 50% of the bypass requirement based on Denver Water's projected reservoir contents being less than 65% full in July. These bypass reductions are reasonably consistent with reductions that occurred most recently from 2003 through 2004. Bypass flows on North and South Trail creeks, Hurd Creek, Hamilton Creek, Cabin Creek, Little Cabin Creek, and Meadow Creek were not reduced because these bypass flows do not have provisions which allow for bypass reductions.

Reductions of bypass flows would occur as Denver Water's average annual demand increases from 285,000 AF under Current Conditions (2006) to 345,000 AF under Full Use of the Existing System because restrictions are anticipated to be imposed more frequently at higher demand levels without additional storage on line. Reductions in bypass flows would be a function of Denver Water's existing operations, not the proposed Moffat Project. The Proposed Action with RFFAs would not increase the conditions under which Denver Water would reduce bypass flows. Since the Proposed Action would increase Denver Water's firm yield, system reliability and flexibility, the conditions under which Denver Water may reduce bypass flows could potentially occur less frequently under the Proposed Action with RFFAs.

A summary of the duration and magnitude of bypass flow reductions by location is provided in Tables 4.6.1-3 and 4.6.1-4. Modeled bypass flows would be reduced in 8 years (1954, 1955, 1956, 1957, 1963, 1964, 1978, and 1979) out of the 45-year study period. The bypass reduction would typically be 30% of the requirement. The total decrease in flow due to bypass flow reductions would range from 443 AF to 1,910 AF. In some instances bypass flows would be reduced in the years following a dry year. This would occur because storage contents may or may not drop below 65% full in July of a dry year depending on the severity of the drought and hydrologic conditions in the preceding years. For example, PACSM results show that Denver Water's total storage contents would not be less than 65% full in July 1977 because that year was preceded by several average and wet years. As a result, bypass flow would not be reduced in 1977, however, due to the severity of the drought that year and low runoff in subsequent years, total storage contents in Denver Water's reservoirs would be less than 65% in the two years following 1977. As a result, modeled bypass flows would be reduced in 1978 and 1979. Similarly, model results show bypass flows would be reduced in the spring of 1957 due to the severity of the drought from 1954 through 1956.

Table 4.6.1-3
Summary of Simulated Bypass Flow Reductions

Year	Fraser River at Winter Park Gage		St. Louis Creek below Denver Water Diversion		Vasquez Creek below Denver Water Diversion		Ranch Creek below Denver Water Diversion		Total Flow Decrease Due to Bypass Reduction (AF)
	Bypass Reduction (AF)	Increase in Days Bypass Reduced	Bypass Reduction (AF)	Increase in Days Bypass Reduced	Bypass Reduction (AF)	Increase in Days Bypass Reduced	Bypass Reduction (AF)	Increase in Days Bypass Reduced	
1954	386	65	309	58	309	65	57	29	**1,061**
1955	510	214	478	203	413	171	157	137	**1,558**
1956	480	182	834	202	439	178	89	114	**1,842**
1957	189	131	76	53	150	119	28	24	**443**
1963	664	142	527	129	509	107	210	121	**1,910**
1964	244	41	375	63	195	41	61	29	**875**
1978	741	189	522	136	512	123	104	49	**1,879**
1979	326	140	200	105	320	151	43	31	**889**

Note:
Bypass flow reductions would occur as Denver Water's average annual demand increases to 345,000 AF/yr under Full Use of the Existing System. The Proposed Action with RFFAs would not increase the frequency of bypass flow reductions.

Table 4.6.1-4
Summary of Daily Bypass Flow Reductions Compared to Current Conditions (2006)

Location/Dates	Current Conditions Bypass (cfs)[1]	Full Use and Proposed Action Bypass (cfs)[2]	Bypass Reduction (cfs)	Bypass Reduction (AF)	No. of Days Bypass Reduced
Fraser River at Winter Park Gage					
June 1 - August 4, 1954	10.0	7.0	3.0	386.0	65
June 1 - September 15, 1955	7.0	5.1	1.9	409.1	107
September 16, 1955 - January 7, 1956	2.9	2.4	0.5	110.4	114
June 7 - September 15, 1956	7.0	5.1	1.9	388.5	101
October 19, 1956 - April 30, 1957	2.8	2.2	0.6	227.0	194
May 15 - May 25, 1957	7.0	5.0	2.0	43.6	11
June 1 - September 15, 1963	10.0	7.0	3.0	636.4	107
September 16 - October 20, 1963	4.0	3.6	0.4	27.7	35
June 23 - August 2, 1964	10.0	7.0	3.0	244.0	41
June 5 - June 13, 1978	10.0	7.0	3.0	53.3	9
June 18 - June 19, 1978	10.0	8.4	1.6	6.3	2
June 29 - September 15, 1978	10.0	7.1	2.9	452.5	79
September 19 - September 24, 1978	4.0	2.8	1.2	13.9	6
September 28 - October 15, 1978	4.0	3.0	1.1	37.5	18
October 18, 1978 - May 5, 1979	4.0	2.8	1.2	464.5	200
May 9 - May 14, 1979	4.0	3.1	0.9	10.5	6
May 15 - May 23, 1979	10.0	8.4	1.6	28.3	9
			Total	**3,539**	**1,104**
St. Louis Creek below Denver Water's Diversion					
June 1 - July 28, 1954	9.7	7.0	2.7	309.0	58
June 1 - September 4, 1955	6.9	5.0	1.9	366.6	96
September 16, 1955 - January 7, 1956	2.0	1.5	0.5	115.1	114
May 15 - September 12, 1956	8.3	5.1	3.2	770.0	121
October 14 - December 7, 1956	2.0	1.5	0.5	54.4	55
December 9 - December 27, 1956	1.7	1.5	0.2	5.5	19
February 9 - March 1, 1957	1.6	1.5	0.1	4.2	22
May 1 - May 15, 1957	2.1	1.5	0.6	16.7	14
May 15 - May 31, 1957	6.6	5.0	1.6	54.8	17
June 1 - September 3, 1963	9.5	7.0	2.5	467.1	95
September 8, 1963	8.5	7.0	1.5	3.0	1
September 16 - September 27, 1963	3.0	2.1	0.9	21.4	12
September 29 - October 9, 1963	3.0	2.1	0.9	18.8	11
October 11 - October 20, 1963	3.0	2.1	0.9	17.1	10
June 13 - August 14, 1964	10.0	7.0	3.0	374.9	63
June 7 - June 12, 1978	10.0	7.0	3.0	35.7	6
June 15 - June 18, 1978	10.0	7.7	2.3	17.9	4
June 26 - August 29, 1978	9.9	7.0	2.9	379.8	65
November 1, 1978 - February 23, 1979	2.8	2.1	0.7	156.5	115

Table 4.6.1-4 (continued)
Summary of Daily Bypass Flow Reductions Compared to Current Conditions (2006)

Location/Dates	Current Conditions Bypass (cfs)[1]	Full Use and Proposed Action Bypass (cfs)[2]	Bypass Reduction (cfs)	Bypass Reduction (AF)	No. of Days Bypass Reduced
April 7 - May 14, 1979	2.9	2.1	0.8	59.3	38
May 19 - May 31, 1979	9.8	7.0	2.8	73.2	13
			Total	**3,321**	**949**
Vasquez Creek below Denver Water's Diversion					
June 1 - August 4, 1954	8.0	5.6	2.4	309.4	65
June 1 - September 15, 1955	5.6	4.0	1.6	339.6	107
November 1 - December 31, 1955	2.1	1.5	0.6	71.9	61
October 24 - October 26, 1955	2.1	1.8	0.3	1.5	3
May 23 - September 15, 1956	5.6	4.0	1.6	368.1	116
October 4, 1956	2.1	1.8	0.3	0.6	1
November 1, 1956 - March 21, 1957	2.1	1.5	0.5	151.5	141
April 17 - May 14, 1957	2.1	1.5	0.6	33.3	28
May 15 - May 25, 1957	5.6	4.0	1.6	34.9	11
June 1 - September 15, 1963	8.0	5.6	2.4	509.4	107
June 23 - August 2, 1964	8.0	5.6	2.4	195.2	41
June 5 - September 15, 1978	8.0	5.6	2.4	490.3	103
November 8 - November 24, 1978	3.0	2.5	0.5	16.2	17
December 29, 1978 - May 15, 1979	3.0	2.1	0.9	244.6	137
May 15 - May 31, 1979	8.0	5.6	2.4	80.9	17
			Total	**2,847**	**955**
Ranch Creek below Denver Water's Diversion					
June 1 - June 25, 1954	4.0	2.9	1.1	54.7	25
July 1 - July 2, 1954	4.0	3.5	0.5	1.9	2
July 4, 1954	4.0	3.9	0.2	0.3	1
July 7, 1954	4.0	3.9	0.1	0.2	1
June 1 - August 31, 1955	2.8	2.0	0.8	138.5	92
September 23 - October 11, 1955	1.3	1.0	0.3	10.9	19
November 3 - November 7, 1955	1.2	1.0	0.2	2.0	5
November 9 - November 15, 1955	1.2	1.0	0.2	2.2	7
November 17 - November 29, 1955	1.1	1.0	0.1	3.2	13
December 6, 1955	1.1	1.0	0.1	0.2	1
May 28, 1956	2.8	2.3	0.5	1.0	1
June 6 - July 9, 1956	2.8	2.0	0.8	53.0	34
July 13 - July 18, 1956	2.7	2.0	0.7	8.2	6
July 24 - July 26, 1956	2.2	2.0	0.2	1.2	3
July 29 - August 3, 1956	2.6	2.0	0.6	7.1	6
August 16 - August 17, 1956	2.4	2.0	0.4	1.4	2
August 20, 1956	2.6	2.0	0.6	1.2	1

Table 4.6.1-4 (continued)
Summary of Daily Bypass Flow Reductions Compared to Current Conditions (2006)

Location/Dates	Current Conditions Bypass (cfs)[1]	Full Use and Proposed Action Bypass (cfs)[2]	Bypass Reduction (cfs)	Bypass Reduction (AF)	No. of Days Bypass Reduced
September 23 - September 26, 1956	1.1	1.0	0.1	1.0	4
October 1 - October 13, 1956	1.1	1.0	0.1	3.2	13
October 21 - November 12, 1956	1.2	1.0	0.2	6.9	23
November 17, 1956	1.1	1.0	0.1	0.2	1
November 21 - November 22, 1956	1.1	1.0	0.1	0.4	2
November 24 - December 9, 1956	1.1	1.0	0.1	4.2	16
December 11 - December 12, 1956	1.1	1.0	0.1	0.4	2
May 2 - May 14, 1957	1.4	1.0	0.4	10.3	13
May 15 - May 25, 1957	2.8	2.0	0.8	17.5	11
June 1 - July 16, 1963	4.0	2.8	1.2	109.1	46
August 4 - August 8, 1963	3.1	2.8	0.3	2.6	5
August 11 - August 20, 1963	3.4	2.8	0.6	12.3	10
August 22 - September 15, 1963	3.8	2.8	1.0	49.4	25
September 16 - October 20, 1963	1.9	1.4	0.5	36.9	35
June 23 - July 18, 1964	4.0	2.8	1.2	59.1	26
July 24, 1964	3.5	2.8	0.7	1.4	1
July 31 - August 1, 1964	2.9	2.8	0.1	0.4	2
June 5 - June 9, 1978	4.0	2.8	1.2	11.9	5
June 29 - August 11, 1978	3.9	2.8	1.1	91.8	44
April 19, 1979	1.5	1.4	0.1	0.2	1
April 24 - April 25, 1979	1.6	1.4	0.2	0.6	2
April 27 - April 28, 1979	1.5	1.4	0.1	0.4	2
May 5 - May 14, 1979	1.8	1.4	0.4	7.9	10
May 15 - May 29, 1979	4.0	2.9	1.0	31.1	15
May 31, 1979	4.0	2.8	1.2	2.4	1
			Total	**749**	**534**

Notes:
[1]The bypass is the average for the period shown.
[2]Bypass flow reductions under each of the Moffat Project alternatives would be the same as under Full Use of the Existing System.

Denver Water's additional diversions under the Proposed Action with RFFAs would result in more days that flows would be reduced to minimum bypass requirements. In addition, tributaries without bypass requirements would be dried up for a longer duration. Streams without bypass requirements would be dried up for a longer period primarily during the summer months from May through July in wet years. The increase in the number of days streams would be dried up is discussed below for each relevant stream segment. While there would be an increase in zero flow days during the runoff period, during winter months most tributaries that do not have bypass requirements are already dried up. This occurs because diversion head gates are set in November or December and are not changed until April of the following year. This typically results in 100% of the flow being diverted during the winter from tributaries without bypass requirements. For example, under Current Conditions (2006) there was no flow below Denver Water's diversion on Jim Creek for 172 days out of 182 days on average from October through March. On Jim Creek, there was almost always zero flow from October through March under Current Conditions (2006) except in two wet years during the study period. This pattern is consistent for all tributaries that do not have bypass requirements at Denver Water's diversion points.

Flow reductions are discussed in more detail in the following sections for each river segment.

Moffat Tunnel Diversions

Additional Moffat Tunnel diversions would be highly concentrated during runoff months primarily in May, June, and July. Additional diversions through Moffat Tunnel would be greatest in wet years following dry year sequences. As shown in Tables H-7.1 through H-7.3, average annual Moffat Tunnel diversions would increase by 13,000 AF or 20%, 17,100 AF or 30%, and 2,000 or 4% in average, wet and dry years, respectively. The maximum monthly and annual increase in diversions would be 33,480 AF and 70,900 AF, respectively. Additional diversions in dry years would occur due to reductions in bypass flows as discussed above. Additional diversions through the Moffat Tunnel would be due in part to Denver Water's demands increasing prior to the Moffat Project coming on line and in part to the Moffat Project. As Denver Water's average annual demand increases from 285,000 AF/yr (Current Conditions) to 345,000 AF/yr (Full Use of the Existing System), Moffat Tunnel diversions would increase by 2,700 AF/yr on average. Moffat Tunnel diversions would increase by an additional 10,300 AF/yr on average due to the Proposed Action with RFFAs.

Additional diversions through Moffat Tunnel would occur primarily in average and wet years during runoff. The maximum monthly average increase in diversions would occur in June, with a 119.9 cubic feet per second (cfs) or 36% increase (Table H-1.28). In dry years, the maximum monthly average increase in diversions would occur in July, with a 21.1 cfs or 23% increase. In wet years, the maximum monthly average increase in diversions would also occur in June, with a 149.3 cfs or 101% increase.

Table H-6.9 shows the percentage of days from May through July that Moffat Tunnel diversions would change. There would be little to no change in diversions (flow change less than 1 cfs) about 27% of the time. Increases in diversions from 1 to 99 cfs would be most common and occur approximately 53% of the time. The maximum daily increase in diversions would be 852 cfs in mid-June (this includes 151 cfs delivered from the Williams Fork River Basin).

Additional diversions from late summer through early spring would be minimal except in infrequent, very wet years. Additional diversions during winter months would occur in 2 years during the 45-year study period. Additional diversions would occur during those months because Gross Reservoir would not be full under the Proposed Action with RFFAs in which case there was additional space in Gross Reservoir to store water diverted through the Moffat Tunnel. In winter months when additional diversions take place, the flow below the diversion structure would typically be equal to or higher than the average winter flow at that location. While there would be an increase in diversions in two winters, there would generally be no flow in tributaries that do not have bypass requirements during the winter. Under Current Conditions (2006), Denver Water typically diverts 100% of the flow during the winter from tributaries that do not have bypass requirements at its diversion points.

In all but 2 years of the study period, monthly diversions during winter months (primarily November and December) would decrease slightly compared to Current Conditions (2006) due to additional diversions for snowmaking purposes in the Fraser River Basin. Some of the water that would be diverted through the Moffat Tunnel under Current Conditions (2006) would be diverted for snowmaking purposes instead because those demands increase in the future. For example, snowmaking diversions from Little Vasquez Creek occur ahead of Denver Water's diversions. As a result, under Current Conditions (2006), in November and December there are sufficient flows to meet snowmaking diversions and any remaining flow is diverted by Denver Water. However, under the Proposed Action with RFFAs, the demand for snowmaking increases considerably. Under that scenario, there is little to no water remaining after water is diverted for snowmaking, so Denver Water's diversions at that location would drop to zero most of the time in November and December.

Fraser River Mainstem Stream Flow

Below Denver Water's mainstem Fraser River Diversion, annual flows would decrease by 1,800 AF or 35% on average, 300 AF or 11% in dry years and 2,900 AF or 28% in wet years. Monthly average flows would decrease by a maximum of 21.5 cfs or 51% in June (Table H-1.29). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 18% in June and 23% in July. In wet years, monthly average flows would decrease by a maximum of 31.5 cfs or 33% in June. Decreases in flow would be greatest in June on average because this coincides with the month when Moffat Tunnel diversions would increase most. The Fraser River at Winter Park gage is located downstream of Denver Water's mainstem Fraser River Diversion and their tributary diversions from Jim Creek, Cub Creek, Buck Creek, and Cooper Creek. Annual flows at this location would decrease by 2,500 AF or 29% on average, 290 AF or 7% in dry years, and 4,200 AF or 25% in wet years. Monthly average flows would decrease by a maximum of 28.7 cfs or 49% in June (Table H-1.33). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 17% in June and July. In wet years, monthly average flows would decrease by a maximum of 45.5 cfs or 33% in June.

Flows would be reduced to the minimum summer bypass requirement of 10 cfs at the Winter Park gage as a result of additional upstream diversions, approximately 6 more days a year on average and a maximum of 22 more days in one year. These flow reductions would occur primarily in June, and May and July to a lesser degree in wet years.

Continuing downstream, the Fraser River would be affected by Denver Water's diversions from Vasquez, Elk, St. Louis, and Ranch creeks as well as additional diversions to meet increased demands for water providers in the Fraser River Basin. Generally, the reduction in flow due to additional diversions rises in the downstream direction however, reductions would be smaller relative to the total stream which is growing. For some reaches, however, flows at locations downstream of Denver Water' Moffat Collection System would be less at certain times of the year if gains do not exceed the amount diverted for irrigation and municipal use. This is primarily an issue following runoff in July and August along the Fraser River mainstem downstream of the confluence of Vasquez Creek and upstream of the confluence with St. Louis Creek, and along St. Louis and Vasquez creeks. While this would magnify the percentage reduction in flow, Denver Water's additional diversions in July and August are typically low because the amount physically and legally available is limited.

Below the confluence with Vasquez Creek, annual flows in the Fraser River would decrease by 7,900 AF or 39% on average, 3,000 AF or 34% in dry years, and 10,800 AF or 28% in wet years. Monthly average flows would decrease by a maximum of 61.2 cfs or 45% in June (Table H-1.38). In dry years, monthly average flows would decrease by a maximum of 7.7 cfs or 36% in June and 39% in July. In wet years, monthly average flows would decrease by a maximum of 89.1 cfs or 29% in June.

Downstream of the confluence with St. Louis Creek, annual flows in the Fraser River would decrease by 13,500 AF or 36% on average, 6,100 AF or 42% in dry years, and 17,600 AF or 23% in wet years. Monthly average flows would decrease by a maximum of 91.0 cfs or 36% in June (Table H-1.44). In dry years, monthly average flows would decrease by a maximum of 13.8 cfs or 53% in July. In wet years, monthly average flows would decrease by a maximum of 123.7 cfs or 22% in June. Flows decrease substantially in the reach below the confluence with Vasquez Creek to below the confluence with St. Louis Creek due to additional diversions by the Town of Fraser. The Town of Fraser's average annual demand is expected to increase from 310 AF under Current Conditions (2006) to 3,326 AF under build-out conditions. Wastewater Treatment Plant (WWTP) discharges attributable to the Town of Fraser's indoor use return downstream of the confluence with St. Louis Creek at the Fraser Sanitation District WWTP (Node 2710). The decrease in flow is significantly less downstream of the WWTP discharge. The increased net depletion to the river attributable to the Town of Fraser water use is approximately 350 AF/yr.

Downstream of the confluence with Crooked Creek, which is located downstream of all of Denver Water's Fraser River Basin diversions, annual flows would decrease by 11,100 AF or 13% on average, 1,500 AF or 4% in dry years, and 15,700 AF or 10% in wet years. Monthly average flows would decrease by a maximum of 104.4 cfs or 21% in June (Table H-1.49). In dry years, monthly average flows would decrease by a maximum of 7.9 cfs or 9% in June. In wet years, monthly average flows would decrease by a maximum of 139.5 cfs or 13% in June.

At the Fraser River at Granby gage, which is located close to the confluence with the Colorado River, annual flows would decrease by 11,400 AF or 12% on average, 1,900 AF or 5% in dry years, and 16,000 AF or 9% in wet years. Monthly average flows would decrease by a maximum of 105.6 cfs or 20% in June (Table H-1.50). In dry years, monthly average flows would decrease by a maximum of 8.9 cfs or 10% in June and 16% in July. In wet years, monthly average flows would decrease by a maximum of 140.6 cfs or 12% in June.

Decreases in flow in the Fraser River Basin are primarily a result of Denver Water's additional diversions through the Moffat Tunnel, which are due in part to Denver Water's demands increasing prior to the Moffat Project coming on line and in part to the Moffat Project. In addition to Denver Water's diversions, average annual municipal and snowmaking demands in the Fraser River Basin would increase by about 10,000 AF. These demands would result in additional depletions of approximately 1,200 AF/yr on average and changes in the timing and quantity of return flows. As shown in Table 4.6.1-5, water supplies are adequate to meet existing demands for water providers in the Fraser River Basin. Under the Proposed Action with RFFAs, however, several water providers would experience average annual shortages ranging from 6 AF to 364 AF. Shortages would be most severe for Grand County Water and Sanitation District (GCWSD) and the Town of Fraser, averaging 364 AF/yr and 247 AF/yr, respectively. These shortages would largely be caused by Denver Water's additional diversions from Vasquez Creek and Little Vasquez Creek as their demand increases from Current Conditions (285,000 AF/yr on average) to Full Use of the Existing System (345,000 AF/yr) prior to implementation of the Proposed Action with RFFAs. Information provided by GCWSD staff indicates they would avoid potential shortages as their demand increases through infrastructure investments. This would likely include a new diversion from the Fraser River mainstem to enable use of their conditional Fraser River water rights, a pump station and Water Treatment Plant. GCWSD's Fraser River diversions would likely not be called out by downstream rights during the winter because their WWTP effluent returns to the Fraser River above other downstream diverters. While GCWSD's shortages may be averted this could increase shortages for other downstream junior diversions or decrease flows since Grand County would be able to divert more water.

Other water providers in the Fraser River Basin that would experience shortages to a lesser degree include Winter Park Recreation and Water and Sanitation District (WPRWSD), Winter Park West Water and Sanitation District, Silver Creek Resort, and the Town of Granby. The majority of additional shortages in the Fraser River Basin would occur due to Denver Water's additional diversions as their average annual demand increases from Current Conditions (2006) to Full Use of the Existing System. Tables H-13.1 through H-13.8 summarize additional shortages anticipated to occur between Current Conditions (2006) and Full Use of the Existing System for Grand County water providers. Additional shortages would occur primarily during the fall and winter months from October through April due to Denver Water's upstream diversions and limited physically and legally available supplies. The shortage for Silver Creek Resort of approximately 18 AF would occur because their build-out demand exceeds the delivery capacity of their existing infrastructure in December. This shortage could potentially be avoided if the capacity of their water supply system was expanded. The shortage for WPRWSD of approximately 6 AF would occur because their build-out demand exceeds the supply that can be provided by their existing water rights. This shortage could potentially be avoided if WPRWSD acquired additional water rights.

Table 4.6.1-5
Summary of Grand County and Summit County Demands and Shortages for the Project Alternative Scenarios

Grand County Average Annual Demands and Shortages (AF)															
Water Provider		Current Conditions (2006)		Difference in Build-out Shortage with the Alternatives											
				Full Use of the Existing System		Proposed Action with RFFAs		Alternative 1c with RFFAs		Alternative 8a with RFFAs		Alternative 10a with RFFAs		Alternative 13a with RFFAs	
Node	Diversion Name	Demand	Shortage	Demand	Shortage	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence
1065	Columbine Lake WD	157	0	303	0	0	0	0	0	0	0	0	0	0	0
1070	Town of Grand Lake	198	0	1,262	1	1	0	1	0	1	0	1	0	1	0
1400	Hot Sulphur Springs	113	0	1,668	70	70	0	70	0	70	0	70	0	70	0
1700	Town of Kremmling	443	0	889	33	32	0	32	0	32	0	32	0	33	0
2130	Winter Park Rec. and W&S (Indoor)	149	0	500	6	6	0	6	0	6	0	6	0	6	0
2390	Winter Park Rec. (Snowmaking)	195	0	470	0	0	0	0	0	0	0	0	0	0	0
2360	Grand County W&SD	688	0	3,713	358	364	6	364	6	364	6	364	6	364	6
2620	Winter Park West W&SD	455	0	617	29	29	0	29	0	29	0	29	0	29	0
2640	Town of Fraser	310	0	3,326	247	247	0	247	0	247	0	247	0	247	0
2850	Silver Creek Resort	186	0	2,951	18	18	0	18	0	18	0	18	0	18	0
2880	Town of Granby	229	0	465	6	6	0	6	0	6	0	6	0	6	0
4100	Arapahoe Basin Snowmaking	45	1	299	60	60	0	60	0	60	0	60	0	60	0

Table 4.6.1-5 (continued)
Summary of Grand County and Summit County Demands and Shortages for the Project Alternative Scenarios

Grand County Average Annual Demands and Shortages (AF)															
Water Provider		Current Conditions (2006)		Difference in Build-out Shortage with the Alternatives											
				Full Use of the Existing System		Proposed Action with RFFAs		Alternative 1c with RFFAs		Alternative 8a with RFFAs		Alternative 10a with RFFAs		Alternative 13a with RFFAs	
Node	Diversion Name	Demand	Shortage	Demand	Shortage	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence
4115	Keystone-Montezuma Domestic	0	0	30	5	5	0	5	0	5	0	5	0	5	0
4135	Keystone Snake River Snowmaking	626	151	1,159	181	181	0	181	0	181	0	181	0	181	0
4140	Keystone Gulch	0	0	78	9	9	0	9	0	9	0	9	0	9	0
4145	Keystone Golf Course	174	0	175	0	0	0	0	0	0	0	0	0	0	0
4150	Keystone Ranch	273	0	279	0	0	0	0	0	0	0	0	0	0	0
4120	Snake River WD	613	2	1,903	24	24	0	24	0	24	0	24	0	24	0
4225	East Dillon WD	292	0	623	1	1	0	1	0	1	0	1	0	1	0
4065/ 4070/ 4090	Town of Breckenridge	2,330	1	3,506	2	2	0	2	0	2	0	2	0	2	0
4085	Breckenridge Golf Course	169	2	169	3	3	0	3	0	3	0	3	0	3	0
4055	Breckenridge Ski Resort	541	0	809	1	1	0	1	0	1	0	1	0	1	0
4170	Copper Mountain W&SD	266	0	1,111	18	18	0	18	0	18	0	18	0	18	0

Table 4.6.1-5 (continued)
Summary of Grand County and Summit County Demands and Shortages for the Project Alternative Scenarios

Grand County Average Annual Demands and Shortages (AF)															
Water Provider		Current Conditions (2006)		Difference in Build-out Shortage with the Alternatives											
				Full Use of the Existing System		Proposed Action with RFFAs		Alternative 1c with RFFAs		Alternative 8a with RFFAs		Alternative 10a with RFFAs		Alternative 13a with RFFAs	
Node	Diversion Name	Demand	Shortage	Demand	Shortage	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence	Shortage	Differ-ence
4175/ 4180	Copper Mountain (outdoor & snowmaking)	488	0	850	0	0	0	0	0	0	0	0	0	0	0
4205	Town of Frisco	846	0	1,975	0	0	0	0	0	0	0	0	0	0	0
4290	Dillon Valley demand	327	0	402	0	0	0	0	0	0	0	0	0	0	0
4295	Town of Dillon	330	0	701	0	0	0	0	0	0	0	0	0	0	0
4340	Buffalo Mountain / Mesa Cortina	297	0	744	0	0	0	0	0	0	0	0	0	0	0
4350	Town of Silverthorne	754	0	2,124	0	0	0	0	0	0	0	0	0	0	0
4400	Eagle's Nest	331	0	1,005	0	0	0	0	0	0	0	0	0	0	0

Notes:
RFFA = reasonably foreseeable future action
W&S = water & sanitation
W&SD = Water & Sanitation District
WD = Water District

As shown in Table 4.6.1-6, a portion of the shortages incurred by three water providers (Grand County Water and Sanitation District, Town of Fraser, and Winter Park West Water and Sanitation District) would be caused by reductions in bypass flows that are anticipated to occur between Current Conditions (2006) and Full Use of the Existing System. As discussed above, Grand County Water and Sanitation District would avoid these potential shortages through infrastructure investments. Shortages due to bypass flow reductions for the Town of Fraser and Winter Park West Water and Sanitation District would occur during the winter from October through March.

Table 4.6.1-6
Summary of Grand County Demands and Shortages with and without Bypass Reductions in the Fraser River Basin

Node	Water Provider	Demand	Average Annual Shortages[1]	
			With Bypass Reductions	Without Bypass Reductions
1400	Hot Sulphur Springs	1,668	70	70
1700	Town of Kremmling	889	33	33
2130	Winter Park Rec and W&S (Indoor)	500	6	6
2360	Grand County W&SD	3,713	358	318
2620	Winter Park West W&SD	617	29	19
2640	Town of Fraser	3,326	247	205
2850	Silver Creek Resort	2,951	18	18
2880	Town of Granby	465	6	6

Notes:
[1]The shortages reported are for Full Use of the Existing System.
W&S = water & sanitation
W&SD = Water & Sanitation District

Jim Creek Stream Flow

Below Denver Water's Jim Creek Diversion, annual flows would decrease by 470 AF or 57% on average and 980 AF or 37% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 5.5 cfs or 54% in June (Table H-1.30). In wet years, monthly average flows would decrease by a maximum of 10.7 cfs or 35% in June.

Flows would be reduced to 0 cfs at this location as a result of Denver Water's additional diversions during the summer approximately 5 more days a year on average and a maximum of 26 more days in one year. These flow reductions would occur primarily in June, and May and July to a lesser degree in wet years.

Cub and Buck Creeks Stream Flow

Below Denver Water's diversions from Cub and Buck creeks, annual flows would decrease by 110 AF or 36% on average and 220 AF or 33% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 1.3 cfs or 58% in June (Table H-1.31). In wet years, monthly average flows would decrease by a maximum of 2.6 cfs or 37% in June.

Flows would be reduced to 0 cfs at this location as a result of Denver Water's additional diversions during the summer approximately 7 more days a year on average and a maximum of 28 more days in one year. These flow reductions would occur primarily in June, and May and July to a lesser degree in wet years.

Cooper Creek Stream Flow

Below Denver Water's diversion from Cooper Creek, annual flows would decrease by 35 AF or 42% on average, 4 AF or 8% in dry years, and 55 AF or 52% in wet years. Monthly average flows would decrease by a maximum of 0.4 cfs or 73% in June (Table H-1.32). In dry years, monthly average decreases in flow would be minimal (less than 0.1 cfs). In wet years, monthly average flows would decrease by a maximum of 0.8 cfs or 70% in June.

Flows would be reduced to 0 cfs at this location as a result of Denver Water's additional diversions during the summer approximately 7 more days a year on average and a maximum of 28 more days in one year. These flow reductions would occur primarily in June, and May and July to a lesser degree in wet years.

Vasquez Creek and Tributaries Stream Flow

Denver Water's diversions from the Williams Fork River Basin are delivered into Vasquez Creek above the Moffat Collection System via the Gumlick and Vasquez tunnels. Below the outfall from the Vasquez Tunnel, annual flows would increase by 2,800 AF or 19% on average, 1,300 AF or 10% in dry years, and 2,200 AF or 15% in wet years. Monthly average flows would increase by a maximum of 19.8 cfs or 48% in July (Table H-1.34). In dry years, monthly average flows would increase by a maximum of 16.7 cfs or 103% in July. In wet years, monthly average flows would increase by a maximum of 13.8 cfs or 22% in June.

Below Denver Water's diversion from Vasquez Creek, annual flows would decrease by 2,400 AF or 31% on average, 160 AF or 5% in dry years, and 3,500 AF or 22% in wet years. Monthly average flows would decrease by a maximum of 23.1 cfs or 41% in June (Table H-1.35). In dry years, monthly average flows would decrease by a maximum of 1.3 cfs or 17% in June and July. In wet years, monthly average flows would decrease by a maximum of 32.2 cfs or 25% in June.

Below Denver Water's diversion from Little Vasquez Creek, annual flows would decrease by 410 AF or 67% on average and 550 AF or 54% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 4.4 cfs or 64% in June (Table H-1.36). In wet years, monthly average flows would decrease by a maximum of 6.4 cfs or 56% in June.

Flows would be reduced to the minimum summer bypass requirement of 8 cfs below Denver Water's Vasquez Creek diversion as a result of additional diversions approximately 13 more days a year on average and a maximum of 67 more days in one year. Below Denver Water's diversion from Little Vasquez Creek, flows would be reduced to 0 cfs as a result of additional diversions during the summer approximately 10 more days a year on average and a maximum of 55 more days in one year. These flow reductions would occur primarily in June and July, and May and August to a lesser degree in wet years.

At the Vasquez Creek gage, annual flows would decrease by 5,500 AF or 53% on average, 2,800 AF or 67% in dry years, and 6,700 AF or 34% in wet years. Monthly average flows would decrease by a maximum of 32.6 cfs or 44% in June (Table H-1.37). In dry years, monthly average flows would decrease by a maximum of 6.2 cfs or 56% in June and 62% in July. In wet years, monthly average flows would decrease by a maximum of 43.7 cfs or 28% in June. Flows decrease substantially at the Vasquez Creek gage due to additional diversions by Grand County Water and Sanitation District. Grand County Water and Sanitation District's average annual demand is expected to increase from 688 AF under Current Conditions (2006) to 3,713 AF under build-out conditions. WWTP discharges attributable to indoor use return downstream of the confluence with St. Louis Creek at the Fraser Sanitation District WWTP (Node 2710). The decrease in flow is significantly less downstream of the WWTP discharge. The increased net depletion to the river attributable to Grand County Water and Sanitation District is approximately 470 AF/yr.

Elk Creek and Tributaries Stream Flow

Below Denver Water's diversions from Elk Creek, West and East Elk creeks, and the East and West forks of main Elk Creek, annual flows would decrease by 280 AF or 32% on average and 410 AF or 23% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 2.9 cfs or 38% in June (Table H-1.39). In wet years, monthly average flows would decrease by a maximum of 4.1 cfs or 24% in June.

Flows would be reduced to 0 cfs at this location as a result of Denver Water's additional diversions during the summer approximately 6 more days a year on average and a maximum of 30 more days in one year. These flow reductions would occur primarily in May and June, and July and August to a lesser degree in wet years.

St. Louis Creek and Tributaries Stream Flow

Below Denver Water's diversion from St. Louis Creek, annual flows would decrease by 1,200 AF or 20% on average, 240 AF or 8% in dry years and 1,600 AF or 14% in wet years. Monthly average flows would decrease by a maximum of 10.7 cfs or 27% in June (Table H-1.40). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 17% in June. In wet years, monthly average flows would decrease by a maximum of 11.5 cfs or 14% in June.

Below Denver Water's diversion from tributaries to St. Louis Creek including West and East St. Louis creeks, Short Creek, Byers Creek, Iron Creek, and Fool Creek, average annual flows would decrease by 1,200 AF or 46% and 1,800 AF or 24% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 11.6 cfs or 43% in June (Table H-1.41). In wet years, monthly average flows would decrease by a maximum of 14.4 cfs or 21% in June.

Below Denver Water's diversion from King Creek, annual flows would decrease by 60 AF or 47% on average and 80 AF or 25% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 0.5 cfs or 44% in June (Table H-1.43). In wet years, monthly average flows would decrease by a maximum of 0.7 cfs or 24% in June.

At the St. Louis Creek near Fraser gage, annual flows would decrease by 2,500 AF or 16% on average, 240 AF or 3% in dry years, and 3,400 AF or 12% in wet years. Monthly average flows would decrease by a maximum of 22.4 cfs or 22% in June (Table H-1.42). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 6% in June. In wet years, monthly average flows would decrease by a maximum of 25.8 cfs or 13% in June.

Flows would be reduced to the minimum summer bypass requirement of 10 cfs below Denver Water's St. Louis Creek diversion as a result of additional diversions approximately 12 more days a year on average and a maximum of 61 more days in one year. Below Denver Water's diversions from St. Louis Creek tributaries and King Creek, flows would be reduced to 0 cfs as a result of additional diversions approximately 13 more days a year on average and a maximum of 69 more days in one year. These flow reductions would occur primarily in June and July, and May and August to a lesser degree in wet years.

Ranch Creek and Tributaries Stream Flow

Downstream of Denver Water's Englewood Ranch Gravity System, which includes diversions from North and South Trail creeks, Hurd Creek, Hamilton Creek, Cabin Creek, and Little Cabin Creek, annual flows would decrease by 310 AF or 4% on average and 570 AF or 5% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 1.9 cfs or 11% in July (Table H-1.45). In wet years, monthly average flows would decrease by a maximum of 5.5 cfs or 21% in May.

Downstream of Denver Water's North Fork Ranch Creek and Dribble Creek diversions, annual flows would decrease by 400 AF or 27% on average and 470 AF or 14% in wet years. The decrease in flows in dry years would be insignificant. Monthly average flows would decrease by a maximum of 3.6 cfs or 23% in June (Table H-1.46). In wet years, monthly average flows would decrease by a maximum of 3.7 cfs or 12% in June.

Downstream of Denver Water's Main Ranch Creek diversion, annual flows would decrease by 450 AF or 16% on average, 80 AF or 6% in dry years, and 480 AF or 9% in wet years. Monthly average flows would decrease by a maximum of 4.5 cfs or 22% in June (Table H-1.47). In dry years, monthly average flows would decrease by a maximum of 0.6 cfs or 14% in June. In wet years, monthly average flows would decrease by a maximum of 4.3 cfs or 11% in June.

Downstream of Denver Water's Middle and South Fork of Ranch Creek diversions, annual flows would decrease by 900 AF or 39% on average and 1,100 AF or 18% in wet years. There would be no decrease in flows in dry years. Monthly average flows would decrease by a maximum of 8.7 cfs or 35% in June (Table H-1.48). In wet years, monthly average flows would decrease by a maximum of 8.8 cfs or 15% in June.

Flows would be reduced to the minimum summer bypass requirement of 4 cfs below Denver Water's main Ranch Creek diversion as a result of additional diversions approximately 9 more days a year on average and a maximum of 60 more days in one year. Below Denver Water's diversions from the Middle and South Forks of Ranch Creek, flows would be reduced to 0 cfs as a result of additional diversions approximately 13 more days a year on average and a maximum of 72 more days in one year. Below Denver Water's diversions from the North Fork of Ranch Creek and Dribble Creek flows would be reduced to 0 cfs as a result of additional diversions approximately 9 more days a year on average and a maximum of 71 more days in one year. These flow reductions would occur primarily in June and July, and May and August to a lesser degree in wet years.

Fraser River Native Stream Flow

As discussed in Section 3.1, Denver Water diverts the greatest percentage of native flow from small tributaries that do not have bypass flow requirements. At locations further downstream along the Fraser River mainstem, the percentage of native flow diverted by Denver Water decreases due to tributary inflows. Tables H-12.1 through H-12.5 and H-12.7 through H-12.15 show the native flow and the amount and percent diverted at Denver Water's diversions in the Fraser River Basin under Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives. Additional native flow diversions would occur primarily in average and wet years during the runoff season from May through July. Under Current Conditions (2006), the average annual percentage of native flow diverted ranges from 19% at the Englewood Ranch Gravity System up to 89% at Denver Water's Jim Creek Diversion. Under the Proposed Action with RFFAs, the average annual percentage of native flow diverted would range from 22% at the Englewood Ranch Gravity System up to 95% at Denver Water's Jim Creek Diversion. The average annual percentage of native flow diverted would increase by 3% at the Englewood Ranch Gravity System up to 15% at Denver Water's diversions from the Middle and South Fork of Ranch Creek, King Creek and St. Louis Creek tributaries. In general the average annual percentage of native flow diverted by Denver Water would increase by about 12% compared to Current Conditions (2006). There would be little to no increase in the percentage of native flow diverted in winter months. The increase in the percentage of native flow diverted would be greatest in June at almost all locations in the Fraser River Basin. In June, the average annual percentage of native flow diverted would increase by about 15 to 20% compared to Current Conditions (2006) at most locations with a maximum increase of 22% at Denver Water's Vasquez Creek Diversion.

Table H-12.6 shows the native flow and the amount and percentage added to Vasquez Creek due to Denver Water's additional diversions from the Williams Fork River Basin, which are delivered to Vasquez Creek via the Gumlick and Vasquez tunnels. Denver Water's additional diversions from the Williams Fork River Basin would almost double the average annual flow in Vasquez Creek under the Proposed Action with RFFAs. The increase in flows below the Vasquez Tunnel outfall would be greatest in May and June in dry years. In June, the average monthly flow in a dry year would increase by 71.7 cfs from 16.8 cfs to 88.4 cfs.

Fraser River Daily Flow Changes

Figures H-4.1 through H-4.69 show average daily diversions through the Moffat Tunnel and hydrographs at locations of interest in the Fraser River Basin for average, dry and wet conditions.

Figures H-5.1 through H-5.11 present flow duration curves at several locations of interest in the Fraser River Basin. As shown by the flow duration curves, flow reductions would occur at higher flow rates, which typically correspond with above average and wet years.

Table H-6.1 shows the percentage of days from May through July that flow changes would occur at several locations of interest in the Fraser River Basin. There would be little to no change in flow (flow change less than 1 cfs) more than 75% of the time at all locations in the basin upstream of the confluence with St. Louis Creek. Below the confluence with St. Louis Creek daily decreases in flow ranging up to 100 cfs would occur 88% of the time or more. Daily decreases in flow would be greatest along the Fraser River mainstem. Table H-6.19 summarizes maximum daily flow reductions at several locations throughout the Fraser River Basin. Below Denver Water's diversion points, reductions in flow would be due to additional diversions attributable to the Moffat Project. At locations further downstream in the basin, such as the Vasquez Creek gage, St. Louis Creek near Fraser gage, Fraser River below St. Louis Creek and the Fraser River at Granby gage, reductions in flow would be caused by a combination of Denver Water's additional diversions and additional municipal diversions by water providers in the Fraser River Basin. The maximum daily flow reductions would typically occur in June and range from 30 cfs to 230 cfs below Denver Water's diversion points. The maximum daily flow reduction in the basin would be 734 cfs at the Fraser River at Granby gage.

Figures H-6.1 through H-6.6 show daily flow changes at several locations in the Fraser River Basin from October 1953 through September 1957. These figures demonstrate the flow reductions that would occur in a wet year following a series of dry years. Denver Water additional diversions during the critical drought period (1954, 1955, and 1956) would be attributable to reductions in bypass flows. Denver Water's Moffat Tunnel diversions in the wet year following the drought would increase by 70,900 AF or 171% under the Proposed Action with RFFAs. This includes an additional 8,300 AF diverted from the Williams Fork River Basin. The increase in diversions would be significant because Denver Water would divert more water to refill the additional firming storage at Gross Reservoir. A small portion of the additional diversions that year would be due to increases in Denver Water's demand under Full Use of the Existing System prior to the Moffat Project coming on line. The reduction in flows in the year following the drought depends on many factors including the length and severity of the drought, storage contents in Denver Water's system, and the physical and legal availability of water.

In some wet years following a drought, flows below Denver Water's diversion points would be more consistent with a dry year or below average year due to additional diversions. The reduction in flows in the year following the drought would increase the frequency and duration of dry year conditions. The change in dry year frequency and duration was evaluated at six locations in the Fraser River Basin including: (1) Fraser River at Winter Park gage, (2) below Denver Water's Jim Creek Diversion, (3) Vasquez Creek gage, (4) St. Louis Creek gage, (5) below Denver Water's main Ranch Creek Diversion, and (6) Fraser River below Crooked Creek. These locations are dispersed throughout the Fraser River Basin and include both tributary and mainstem locations with and without bypass requirements. Annual flows for Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives were ranked based on volume. The bottom 25th percentile was assumed to include dry and below average years. Under the Proposed Action with RFFAs, the number of years with annual flows in the bottom 25th percentile would increase from 12 years to 14 years (a 17% increase) at Denver Water's Ranch Creek Diversion and 12 to 29 years (an increase of 142%) at the Vasquez Creek gage as shown in Tables H-15.1 through H-15.6. The increase in the frequency of dry year conditions would be greatest along tributaries that Denver Water diverts from. The significant increase in dry year conditions at the Vasquez Creek gage would be caused by the combination of additional diversions by Grand County Water and Sanitation District and Denver Water. Grand County Water and Sanitation District's average annual demand is expected to increase from 688 AF under Current Conditions (2006) to 3,713 AF under build-out conditions. Denver Water's average annual diversions from Vasquez Creek and Little Vasquez Creek would increase by approximately 2,800 AF/yr.

This analysis also shows the duration and recurrence of back-to-back dry years will increase under the Proposed Action with RFFAs. Under Current Conditions (2006), there would be a total of 3 sets of at least 2 back-to-back dry or below average years, with the longest period being 3 years in a row at the Fraser River at Winter Park gage. Under the Proposed Action with RFFAs, there would be 4 sets of at least 2 back-to-back dry or below average years, with the longest period being 4 years in a row at that location. At the Vasquez Creek gage, there would be a total of 4 sets of at least 2 back-to-back dry or below average years under Current Conditions (2006), with the longest period being 3 years in a row. Under the Proposed Action with RFFAs, there would be 5 sets of at least 2 back-to-back dry or below average years, with the longest period being 6 years in a row at that location. Results at the other locations are more similar to the Fraser River at Winter Park gage.

Fraser River Peak Flow Changes

Denver Water's additional diversions would affect the magnitude, timing, frequency, and duration of peak flows below their diversion points. The Nature Conservancy's Indicators of Hydrologic Alteration (IHA) was used to evaluate changes in the flow regime at 12 locations in the Fraser River Basin. The IHA is a statistically based program for comparing hydrologic regimes before versus after a river has been altered by human activities. The data series used for pre- and post-impact periods consisted of daily data from 1947 through 1991 for Current Conditions (2006) and the Proposed Action with RFFAs, respectively.

IHA Version 7.1.0.10 (Copyright 1996-2009, The Nature Conservancy) was used to analyze what are termed "Environmental Flow Components" (EFC) of the stream regime. IHA was used to calculate parameters for four different types of EFCs: low flows, high flow pulses, small floods and large floods. Each of the EFC flow types analyzed is described below:

Low Flows – This is the dominant flow condition in most rivers and is the base level that exists after a rainfall event or snowmelt period has passed and associated surface runoff from the contributing watershed has subsided. Low flow levels are sustained by groundwater discharge to the river.

High-Flow Pulses – High-flow pulses include water rises that occur during rainstorms or brief periods of snowmelt when the river rises above its low-flow level. High-flow pulses include water rises that do not overtop the channel banks.

Small Floods – Small floods include river rises that overtop the main channel but do not include more extreme, less frequent floods. For this analysis, small floods were defined as flows equal to or greater than the 2-year flood event but less than the 10-year flood event.

Large Floods – Large floods include more extreme, less frequent events and were defined as floods equal to or greater than the 10-year flood event.

Values for 30 ecologically-relevant hydrologic parameters were calculated for each year in the data series. Non-parametric statistics (median values) were used for computing EFC parameters. The attributes evaluated are based on fundamental characteristics of hydrologic regimes including flow magnitude, flow timing, flow frequency, flow duration, and the flow rate of change. Appendix H-14 includes detailed output from the IHA analysis. Inter-annual statistics were computed by calculating measures of central tendency and dispersion for the 30 attributes. The coefficient of dispersion was defined as equal to (75^{th} percentile – 25^{th} percentile)/50^{th} percentile, while the high and low pulse thresholds were set as the median plus or minus 17%. The deviation of the post-impact period from the pre-impact is defined as the Deviation Factor, which is equal to (Post-impact value – Pre-impact value)/Pre-impact value.

Tables H-14.1 through H-14.3 summarize changes in the magnitude, duration, and timing of high-flow pulses, small floods and large floods at each location analyzed. Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the average peak flow for an average year and wet year based on the average and wet year daily hydrographs included in Appendix H-4.

There would be little to no change in median monthly low flows at locations high in the Fraser River Basin. There would be no change in the median low flow along the tributaries to the Fraser River that were evaluated. Below Denver Water's Fraser River Diversion, the median monthly low flow would decrease 0.5 cfs or less during the summer and less than 0.1 cfs during the winter. Further downstream along the Fraser River mainstem below the confluence with St. Louis Creek, the median monthly low flow would decrease up to 9.1 cfs during the summer and about 7 cfs during the winter. Decreases in low flows during the winter are primarily due to additional diversions by the Town of Fraser. WWTP discharges attributable to the Town of Fraser's indoor use return downstream of the confluence with St. Louis Creek at the Fraser Sanitation District WWTP, therefore, decreases in low flows are less below the WWTP outfall. Below the confluence with Crooked Creek, the median monthly low flow would decrease up to 4.8 cfs during the summer and less than 0.7 cfs during the winter.

At the locations evaluated, the magnitude of small flood peak flows would decrease up to 9 cfs (10%) along tributaries to the Fraser River and up to 56 cfs (8%) along the Fraser River mainstem below St. Louis Creek (Table H-14.1). At some locations, such as King Creek and the tributaries and mainstem of Ranch Creek, there would be little to no change in small flood peak flows. Throughout the basin there would be minimal change (+/- up to three days) in the timing of the small flood peak, which typically occurs in mid- to late June. There would be a significant decrease in the duration of a small flood along tributaries to the Fraser River. The duration of a small flood would decrease by about 2 days up to 18 days along tributaries to the Fraser River. The duration of a small flood would be reduced because it would typically take longer to fill an enlarged Gross Reservoir, in which case diversions would continue for a longer period during runoff. The reduction in the duration of a small flood generally decreases at locations further downstream in the basin and along the Fraser River mainstem. At the Fraser River below Crooked Creek the duration of a small flood would actually increase by 1 day.

There would be little change in the timing and magnitude of peak flows for large floods at the locations evaluated with the exception of the Fraser River below Crooked Creek. At the Fraser River below Crooked Creek the large flood peak flow would decrease by 392 cfs or 18% (Table H-14.2). This reduction is mainly due to changes in the timing and magnitude of the peak of the large flood in one year of the study period at that location. There would be a significant decrease in the duration of large floods along the tributaries and mainstem of the Fraser River. The duration of a large flood would decrease from 8 days below Denver Water's King Creek Diversion up to 45 days below Denver Water's main Ranch Creek Diversion and North Fork Ranch Creek and Dribble Creek diversions.

The magnitude of high flow pulses would increase or decrease by up to 8 cfs along tributaries to the Fraser River and up to 10 cfs along the Fraser River mainstem locations evaluated (Table H-14.3). There would be little change in the duration of high flow pulses (decrease by 1 day or less). In general there would be little change in the timing of high flows pulses (+/- up to 9 days) with the exception of the Fraser River below St. Louis Creek. At that location the median timing of high flow pulses would occur 44 days later.

As shown in Table H-14.4, the magnitude of the peak flow in an average year would decrease less than 1 cfs at the King Creek Diversion up to 115 cfs at the Fraser River below Crooked Creek. In general, there would be little to no change in the timing of the peak flow, however, at one location it would be delayed up to 10 days. As shown in Table H-14.5, the magnitude of the wet year peak flow would decrease less than 5 cfs at the tributary locations evaluated up to 117 cfs at the Fraser River below Crooked Creek. In general, the reduction in the average and wet year peak flows would be least at locations higher in the basin along tributaries and increase along the Fraser River mainstem lower in the basin. At most locations there would be little to no change in the timing of the wet year peak flow, however, at one location the peak would be delayed up to 7 days and at two locations the wet year peak flow would occur 4 days earlier.

Changes in the frequency of peak flows for different flood recurrence intervals are discussed in the following section and in Section 4.6.3.

Fraser River Floodplain

Under the Proposed Action with RFFAs, more water would be exported from the Fraser River Basin and there would be more in-basin use of Fraser River water compared to Current Conditions (2006). Additional Moffat Tunnel diversions would occur primarily in average and wet years during runoff. As a result, it is expected that flood flows would be less than they are under Current Conditions (2006).

The maximum annual flow series for four different locations in the Fraser River Basin were analyzed to verify this generalization. Locations analyzed correspond with four of the sampling sites in the Fraser River Basin including FR1, FR2, FR3, and FR4 (refer to Section 3.3.5.1 for a description of the sampling sites). In all cases, peak flows for a given recurrence interval under the Proposed Action with RFFAs were equal to or less than peak flows for the same recurrence interval under Current Conditions (2006). The following observations can be made:

- On the mainstem, the lowest 20% of annual peak flood flows and the highest annual peak would not be significantly different from Current Conditions (2006), and all other flood flows would be reduced.
- On St. Louis Creek, annual peaks associated with recurrence intervals greater than 6.6 years would be unchanged, while all other annual peaks would be less than under Current Conditions (2006). The four lowest annual peaks differ by 1.5 cfs or less.
- On Ranch Creek, annual peaks associated with recurrence intervals great than 3.3 years would be the same as under Current Conditions (2006), while all other annual peaks would be less.

To summarize, areas of inundation would generally be smaller throughout the basin for the 2- and 5-year flood events. For less frequent floods, the floodplain along the Fraser River may be smaller than under Current Conditions (2006) but have similar extents along the tributaries.

Williams Fork River

Changes in Williams Fork River flows would be due to the combined effects of the following actions.

1. Releases of 5,412.5 AF/yr would no longer be made from Williams Fork Reservoir for endangered fish in the 15-Mile Reach. This change would affect Williams Fork Reservoir operations, including the timing and quantity of reservoir storage and releases and flows in the Williams Fork River. Fish flow releases are typically made in the late summer or fall when flows drop below the U.S. Fish and Wildlife (USFWS) flow recommendations. The timing and amount released depends on the type of year (average, wet, or dry). Flows below Williams Fork Reservoir would be less by the amount released for 10,825 Water purposes under Current Conditions (2006). Conversely, there would be higher flows in the spring of the following year when Williams Fork Reservoir fills and spills, and higher contents in Williams Fork Reservoir in years that the reservoir does not fill and spill.
2. Denver Water's growth in demand between Current Conditions (2006) and the Proposed Action with RFFAs would result in additional Gumlick Tunnel diversions. Denver Water's average annual demand would increase from 285,000 AF under Current Conditions (2006) to 363,000 AF/yr under the Proposed Action with RFFAs. Gumlick Tunnel diversions would increase in response to a higher demand, however, additional diversions would be limited by available storage capacity at Gross Reservoir and other system constraints. When more water is diverted through Gumlick Tunnel, that water is not available to fill Williams Fork Reservoir.
3. Denver Water's additional trans-basin diversions from the Fraser, Williams Fork, and Blue rivers would result in increased exchange releases from Williams Fork Reservoir to cover Denver Water's out of priority depletions and increased substitution releases to

cover Denver Water's out of priority storage in Dillon Reservoir when Green Mountain Reservoir does not fill.

4. Big Lake Ditch would no longer divert for irrigation in the Reeder Creek drainage due to the expiration of the Denver Water's temporary Big Lake Ditch contract. Under Current Conditions (2006), a significant portion of the water diverted under the Big Lake Ditch was delivered for irrigation in the Reeder Creek drainage. Return flows from Big Lake Ditch deliveries to the Reeder Creek drainage return to the Colorado River below the confluence with the Williams Fork River. By 2032, Big Lake Ditch deliveries to the Reeder Creek drainage would be curtailed and all Big Lake Ditch return flows would accrue to the Williams Fork River. This action affects the timing and quantity of flows in Williams Fork River and the Colorado River. The change in Big Lake Ditch operations in the future would result in approximately 10,000 AF/yr less diverted from Williams Fork River on average and a corresponding increase in flows in the Williams Fork River Basin compared to Current Conditions (2006). Return flows to the Colorado River would decrease by approximately 8,000 AF/yr. The abandonment of all Big Lake Ditch diversions to the Reeder Creek Basin would allow Denver Water to capture additional water from Williams Fork River for storage in Williams Fork Reservoir when its Williams Fork Reservoir water rights are in priority. Changes in the inflow to Williams Fork Reservoir would be greatest from June through October when differences in Big Lake Ditch depletions and return flows are greatest. Depending on the type of year (average, wet, or dry), flows below Williams Fork Reservoir may increase or decrease due to the effects of this action.

A description of changes in modeled diversions and flows in the Williams Fork River Basin is provided below.

Gumlick Tunnel Diversions

The Williams Fork River upstream of the Williams Fork Reservoir is directly affected by changes in Denver Water's diversions through Gumlick Tunnel when additional storage is added to the Moffat Collection System. Additional diversions through the Gumlick Tunnel would be due in part to Denver Water's demands increasing prior to the Moffat Project coming on line and in part to the Moffat Project. As Denver Water's average annual demand increases from 285,000 AF/yr (Current Conditions) to 345,000 AF/yr (Full Use of the Existing System), Gumlick Tunnel diversions would increase by 900 AF/yr on average. Gumlick Tunnel diversions would increase by an additional 1,900 AF/yr on average due to the Moffat Project. With increased storage capacity on the East Slope, Denver Water would be able to divert water that it is currently unable to capture without additional storage. Increases in Gumlick Tunnel diversions would occur primarily during runoff in June and July, and would be greatest in wet years following dry year sequences.

As shown in Tables H-7.1 through H-7.3, annual Gumlick Tunnel diversions would increase by 2,800 AF or 32% on average, 1,300 AF or 14% in dry years, and 2,200 AF or 34% in wet years. The maximum monthly and annual increase in diversions would be 6,300 AF and 10,400 AF, respectively. There would be no or minimal additional diversions in five years of the study period because Denver Water already diverts the maximum amount physically and legally available under their existing water rights. Additional diversions would occur primarily in May, June, and July. The maximum monthly average increase in diversions would occur in July, with a 19.8 cfs or 101% increase (Table H-1.51). In dry years, the maximum monthly average increase in diversions would also occur in July, with a 16.7 cfs or 237% increase on average. Additional diversions would occur in dry years as Denver Water's average annual demand increases from 285,000 AF (Current Conditions) to 345,000 AF (Full Use of the Existing System). Additional diversions in dry years would not be due to the Proposed Action. In wet years, the maximum monthly average increase in diversions would occur in June, with a 13.8 cfs or 165% increase on average. The monthly average increase in diversions in wet years is actually less than in average years because diversions are already high in most wet years and the opportunity to divert more is limited given storage constraints at Gross Reservoir and piping constraints in the Denver Water Moffat Collection System.

Table H-6.9 shows the percentage of days from May through July that Gumlick Tunnel diversions would change. There would be little to no change in diversions (flow change less than 1 cfs) about 94% of the time. Increases in diversions from 1 to 99 cfs would occur approximately 5% of the time. The maximum daily increase in diversions would be 200 cfs in early July.

Additional diversions in winter months from late summer through early spring would be minimal except in infrequent, very wet years. Additional diversions during winter months would occur in 2 years during the 45-year study period. Additional diversions would occur during those months because Gross Reservoir was not full in which case there was additional space in Gross Reservoir to store water diverted through the Gumlick Tunnel. Since the diversion dams in the Williams Fork Collection System cannot be adjusted in the wintertime because they are snowed in, Denver Water has the ability to release all or a portion of water diverted by that system rather than allowing it to flow through the Gumlick Tunnel if Gross Reservoir is full. In winter months when additional diversions take place, the flow below the diversion structure would be equal to or higher than the average winter flow at those locations.

Williams Fork River Mainstem and Tributaries Stream Flow

Denver Water diverts water for delivery through the Gumlick Tunnel from four headwater tributaries including Steelman Creek, Bobtail Creek, Jones Creek, and McQueary Creek. Below Denver Water's Steelman Creek diversion, annual flows would decrease by 690 AF or 33% on average, 330 AF or 82% in dry years, and 500 AF or 12% in wet years. At this location, monthly average flows would decrease by a maximum of 4.9 cfs or 43% in July (Table H-1.52). In dry years, monthly average flows would decrease by a maximum of 4.0 cfs or 84% in July. In wet years, monthly average flows would decrease by a maximum of 3.6 cfs or 54% in May. Below Denver Water's Bobtail Creek diversion, annual flows would decrease by 1,200 AF or 34% on average, 590 AF or 90% in dry years, and 1,000 AF or 13% in wet years. At this location, monthly average flows would decrease by a maximum of 8.8 cfs or 45% in July (Table H-1.53). In dry years, monthly average flows would decrease by a maximum of 8.1 cfs or 89% in July. In wet years, monthly average flows would decrease by a maximum of 6.6 cfs or 9% in June. Below Denver Water's Jones Creek diversion, annual flows would decrease by 360 AF or 31% on average, 180 AF or 78% in dry years, and 260 AF or 11% in wet years. At this location, monthly average flows would decrease by a maximum of 2.8 cfs or 43% in July (Table H-1.54). In dry years, monthly average flows would decrease by a maximum of 2.2 cfs or 83% in July. In wet years, monthly average flows would decrease by a maximum of 1.8 cfs or 51% in May. Below Denver Water's McQueary Creek diversion, annual flows would decrease by 510 AF or 37% on average, 180 AF or 83% in dry years, and 410 AF or 14% in wet years. At this location, monthly average flows would decrease by a maximum of 3.6 cfs or 28% in June (Table H-1.55). In dry years, monthly average flows would decrease by a maximum of 2.4 cfs or 81% in July. In wet years, monthly average flows would decrease by a maximum of 2.6 cfs or 10% in June.

At the Williams Fork River below Steelman Creek gage, which is located below all of Denver Water's Gumlick Tunnel diversions, annual flows would decrease by 2,800 AF or 29% on average, 1,300 AF or 59% in dry years, and 2,200 AF or 11% in wet years. Monthly average flows would decrease by a maximum of 19.8 cfs or 40% in July (Table H-1.56), which coincides with the month when Gumlick Tunnel diversions would increase most. In dry years, monthly average flows would decrease by a maximum of 16.7 cfs or 80% in July. In wet years, monthly average flows would decrease by a maximum of 13.9 cfs or 8% in June. Moving downstream to the Williams Fork near Leal gage, the volume of change stays the same but the percentage reduction in flow is less because the stream is gaining.

Flows below Williams Fork Reservoir reflect the combined effect of additional Gumlick Tunnel diversions, the termination of the Big Lake Ditch contract, and changes in Williams Fork Reservoir operations, including spills, substitution and exchange releases, releases for 10,825 Water purposes, and power releases to achieve operational goals. Annual outflow from Williams Fork Reservoir would increase by 7,200 AF or 8% on average, 9,100 AF or 13% in dry years, and 15,300 AF or 11% in wet years. Monthly average changes in outflow would range from a maximum decrease of 7.1 cfs or 3% in August to a maximum increase of 55.2 cfs or 43% in July (Table H-1.57). In dry years, monthly average changes in outflow would range from a maximum decrease 1.0 cfs or 1% in April to a maximum increase of 98.3 cfs or 148% in July. In wet years, monthly average changes in outflow would range from a maximum decrease 15.4 cfs or 3% in June to a maximum increase of 97.6 cfs or 26% in July.

Williams Fork River Native Stream Flow

Tables H-12.16 through H-12.19 show the native flow and the amount and percent diverted at Denver Water's diversions from the upper Williams Fork River tributaries under Current Conditions (2006), Full Use of the Existing System, No Action, and each of the action alternatives. As discussed above, additional native flow diversions would occur primarily in average and wet years during the runoff season from May through July. Under Current Conditions (2006), the average annual percentage of native flow diverted from the upper William Fork River Basin ranges from 49% at Denver Water's Jones Creek diversion up to 55% at their McQueary Creek diversion. Under the Proposed Action with RFFAs, the average annual percentage of native flow diverted would range from 65% at Denver Water's Jones Creek diversion to 72% at their McQueary Creek diversion. The average annual percentage of native flow diverted would increase by approximately 16% compared to Current Conditions (2006). There would be little increase in the percentage of native flow diverted in winter months. The increase in the percentage of native flow diverted from the upper Williams Fork River tributaries would be greatest in July. In July, the average percentage of native flow diverted by Denver Water from the upper Williams Fork River tributaries would increase by about 30% compared to Current Conditions (2006) with a maximum increase of 33% at Denver Water's Jones Creek diversion.

Williams Fork River Daily Flow Changes

Figures H-4.70 through H-4.90 show average daily diversions through Gumlick Tunnel and average daily hydrographs at the locations of interest in the Williams Fork River Basin for average, dry and wet conditions.

Figures H-5.12 through H-5.14 present flow duration curves for Steelman Creek below Denver Water's diversion, Williams Fork River below Steelman Creek, and Williams Fork Reservoir outflow, respectively. Flow duration curves for Bobtail, Jones, and McQueary creeks below Denver Water's diversion points were not developed since they are very similar to the flow duration curve for Steelman Creek. As shown by the flow duration curves, flow reductions would occur at higher flow rates, which typically correspond with wet years.

Table H-6.2 shows the percentage of days from May through July that flow changes would occur below Denver Water's Steelman Creek Diversion, at the Williams Fork River below Steelman Creek gage, and below Williams Fork Reservoir. There would be little to no change in flow (flow change less than 1 cfs) over 80% of the time at locations upstream of the Williams Fork River below Steelman Creek gage and about 65% of the time below Williams Fork Reservoir. Increases in flow ranging up to 100 cfs would occur approximately 17% of the time below Williams Fork Reservoir. Table H-6.19 summarizes maximum daily flow reductions at similar locations. Below Denver Water's diversions from the upper Williams Fork River tributaries, reductions in flow would be due to additional diversions attributable to the Moffat Project. At locations further downstream in the basin, reductions in flow would be caused by a combination of Denver Water's additional diversions and other RFFAs including termination of the Big Lake Ditch contract and changes in Williams Fork Reservoir releases for endangered fish. The maximum flow reductions would occur in July and range from 60 cfs below Denver Water's Steelman Creek diversion to 640 cfs below Williams Fork Reservoir.

Figures H-6.7 and H-6.8 show daily flow changes below Denver Water's diversion from Bobtail Creek and at the Williams Fork River below Steelman Creek gage from October 1953 through September 1957. These figures demonstrate flow reductions that would occur in a sequence of dry years followed by a wet year. Denver Water would divert additional water during the critical drought in 1954, 1955, and 1956 because there are no bypass flow requirements below Denver Water's diversions in the Williams Fork River Basin and there is space in Gross Reservoir. Additional diversions would be limited because the amount physically and legally available is less than average in those years. In the wet year following the drought (1957), Gumlick Tunnel diversions would increase by approximately 8,300 AF or 200% compared to Current Conditions (2006). The increase in diversions would be significant in 1957 because Denver Water would divert more water to refill additional storage at Gross Reservoir. A small portion of the additional diversions that year would be due to increases in Denver Water's demand under Full Use of the Existing System prior to the Moffat Project coming on line. Additional diversions in 1957 are most significant in July after the peak flow occurs. Therefore, although there is a significant increase in the amount of water diverted in 1957, the peak flow that occurs at the end of June at these locations would be unaffected. The reduction in flows in the year following the drought depends on many factors including the length and severity of the drought, storage contents in Denver Water's system, and the physical and legal availability of water.

In some wet years following a drought, flows below Denver Water's diversion points would be more consistent with a dry year or below average year due to additional diversions under the Proposed Action with RFFAs. The reduction in flows in the year following the drought would increase the frequency and duration of dry year conditions. The change in dry year frequency and duration was evaluated at two locations in the Williams Fork River Basin including: (1) Steelman Creek below Denver Water's diversion, and (2) Williams Fork River below Steelman Creek gage. Annual flows for Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives were ranked based on volume. The bottom 25th percentile was assumed to include dry and below average years. The number of years in the bottom 25th percentile would increase by 5 years from 12 years to 17 years at both locations analyzed, as shown in Tables H-15.7 and H-15-8.

This analysis also shows the duration and recurrence of back-to-back dry years will increase under the Proposed Action with RFFAs. Under Current Conditions (2006), below Denver Water's Steelman Creek diversion, there would be a total of 4 sets of at least 2 back-to-back dry or below average years, with the longest period being 3 years in a row. There would be 5 sets of at least 2 back-to-back dry or below average years, with the longest period being 4 years in a row at that location. At the Williams Fork River near Steelman Creek gage there would be 4 sets of at least 2 back-to-back dry or below average years under Current Conditions (2006), with the longest period being 3 years in a row. There would be 5 sets of at least 2 back-to-back dry or below average years, with the longest period being 4 years in a row.

Williams Fork River Peak Flow Changes

The combined effect of Denver Water's additional diversions and other RFFAs would affect the magnitude, timing, frequency, and duration of peak flows in the Williams Fork River Basin. The Nature Conservancy's Indicators of Hydrologic Alteration (IHA) was used to evaluate changes in the flow regime below Denver Water's diversion from Bobtail Creek and at the Williams Fork River above Darling Creek gage. See the section on the Fraser River for a discussion of IHA and the methodology used to evaluate changes in the flow regime. Appendix H-14 includes detailed output from the IHA analysis.

Tables H-14.1 through H-14.3 summarize changes in the magnitude, duration, and timing of high-flow pulses, small floods and large floods at the locations analyzed. Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the peak flow for an average year and wet year based on the daily hydrographs included in Appendix H-4.

There would be little to no change in median monthly low flows at locations high in the Williams Fork River Basin. There would be no change in the median low flow below Denver Water's Bobtail Creek diversion. At the Williams Fork River above Darling Creek gage, the median monthly low flow would decrease less than 0.5 cfs during the summer and less than 0.2 cfs during the winter.

There would be no change in the magnitude or timing of the small flood peak flow below the Bobtail Creek diversion, however, the duration of the flood event would be reduced by 18 days. At the Williams Fork River above Darling Creek gage, the median small flood peak flow would increase by 5 cfs, the duration would decrease by 1.5 days, and the timing would shift less than one day earlier.

There would be no change in the timing and magnitude of the large flood peak flow at the locations evaluated, however, the duration of the large flood would decrease by 27 days at the Bobtail diversion and 5 days at the Williams Fork River above Darling Creek gage.

The magnitude of high flow pulses would increase by 19 cfs and less than 1 cfs at the Bobtail Creek diversion and Williams Fork River above Darling Creek gage, respectively. The duration of high flow pulses would not change, however, the median timing of high flow pulses would shift 18 days and 13 days earlier at the Bobtail Creek diversion and Williams Fork River above Darling Creek gage, respectively.

Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the peak flow for an average year and wet year at the Bobtail Creek Diversion and the Williams Fork River above Darling Creek gage. The magnitude of the peak flow in an average year would decrease by 8 cfs at the Bobtail Creek Diversion and 17 cfs at the Williams Fork River above Darling Creek gage. There would be no change in the timing of the peak flow in an average year. There would be no change in the magnitude or timing of the wet year peak flow at the Bobtail Creek Diversion and Williams Fork River above Darling Creek gage.

Changes in the frequency of peak flows for different flood recurrence intervals are discussed in the following section and in Section 4.6.3.

Williams Fork River Floodplain

Analysis of annual peak flows at the two sampling sites, WF1 and WF2, upstream of Williams Fork Reservoir (refer to Section 3.3.5.2 for a description of sampling sites) show that annual flood flows would never be greater under the Proposed Action with RFFAs than under Current Conditions (2006). The annual floods associated with recurrence intervals greater than 2.2 years are the same in the two scenarios, indicating that the Gumlick Tunnel would already be diverting as much as possible under Current Conditions (2006) during peak flow, and diversions would be no greater under the Proposed Action with RFFAs. The floodplain above Williams Fork Reservoir for high flow, low frequency events would be the same as it is for Current Conditions (2006).

Flows downstream of Williams Fork Reservoir during peak runoff would be greater under the Proposed Action with RFFAs than under Current Conditions (2006), except in dry years. Differences are due primarily to the expiration of the Big Lake Ditch contract and termination of 10,825 Water releases. These factors contribute to consistently higher reservoir contents under the Proposed Action with RFFAs. With higher reservoir levels, spills in average and wet years tend to be greater. The biggest differences occur for recurrence intervals of 2.4 to 3.5 years. These flood events would increase by approximately 200 cfs, or up to 42% higher than peak flows under Current Conditions (2006) for similar recurrence intervals. For recurrence intervals greater than 10 years, peak flows are 50 to 80 cfs, or 3% to 7% higher than peak flows under Current Conditions (2006) for similar recurrence intervals.

Colorado River

Colorado River Stream Flow

For the purpose of analyzing changes in flows along the Colorado River, modeled diversions and stream flows were analyzed below the Windy Gap diversion, below the confluence with the Williams Fork River and at the Colorado River near Kremmling gage. Flows in the Colorado River above the confluence with the Fraser River are virtually the same under all EIS alternatives.

Changes in Colorado River mainstem flows would be primarily due to the combined effects of Denver Water's growth in demand and the Moffat Project, WGFP, additional municipal diversions along the mainstem including changes in the timing and quantity of associated return flows, and changes along the contributing tributaries including the Fraser River, Williams Fork River, Muddy Creek, and Blue River. Changes along the tributaries are discussed in separate sections for each tributary.

Changes in Colorado River flows would be directly related to the increase in Denver Water's demand and the increase in storage capacity at Gross Reservoir. Flow reductions due to Denver Water's additional diversions from the Fraser, Williams Fork, and Blue river basins would be translated downstream and into the Colorado River. Other projects that would affect flows along the Colorado River include the WGFP, which is anticipated to be on line prior to the Moffat Project. The WGFP would result in additional diversions at the Windy Gap Project diversion site on the Colorado River, which is downstream of the confluence of the Colorado and Fraser rivers. The WGFP is anticipated to generate approximately 26,000 AF/yr of firm yield for the project participants, through an increase in Windy Gap diversions and a reduction in Windy Gap spills from Granby Reservoir. Similar to the Moffat Project, additional diversions would occur primarily in May, June and July and would be greatest in wet years following dry years. The WGFP would also affect the timing and quantity of Granby Reservoir spills. In addition to the WGFP, there would be additional municipal diversions along the Colorado River mainstem. Municipal and industrial diversions from the mainstem from the headwaters to Kremmling would increase by approximately 3,200 AF/yr on average and there would be associated changes in depletions and the timing and quantity of return flows.

Changes in surface water flows described for the Fraser River, Williams Fork River, Muddy Creek, and Blue River would be translated downstream and into the Colorado River. For example, the effects on Colorado River flows from the cessation of 10,825 Water releases from Williams Fork and Wolford Mountain reservoirs would be similar to the effects described for Williams Fork River and Muddy Creek. When fish releases are not made from Williams Fork and Wolford Mountain reservoirs in the late summer and fall, flows in the Colorado River below the confluence with these tributaries would be less by a commensurate amount. The reduction in fish flow releases would be offset by a corresponding change in the amount of water stored in these reservoirs during runoff. The cessation of 10,825 Water releases would affect the timing of flows in the Colorado River but would have little effect on the average annual quantity of flow. Since the modeling was completed for the Moffat Project EIS, the 10,825 Water Supply Study led to the identification of a preferred alternative, which consists of releases from Ruedi and Granby reservoirs. While 10,825 Water releases will no longer be made from Williams

Fork and Wolford Mountain reservoirs, about half of the 10,825 Water release will be made from Granby Reservoir under the preferred alternative. This will offset approximately half of the flow reduction currently reflected in PACSM that would occur in the fall in the Colorado River below the confluence with Williams Fork River and Muddy Creek due to the cessation of 10,825 Water releases from Williams Fork and Wolford Mountain reservoirs.

As shown in Tables H-7.1 through H-7.3, annual flows below Windy Gap would decrease by 28,900 AF or 19% on average, 56,000 AF or 13% in wet years, and change in flows below Windy Gap would be insignificant in a dry year. Changes in Colorado River flows below Windy Gap would be due primarily to the combined effects of Denver Water's additional diversions from the Fraser River Basin and additional diversions attributable to the WGFP in years that are above average and wet, and in particular, in wet years following dry year sequences. Annual flows below the confluence with the Williams Fork River would decrease by 22,000 AF or 8% on average, increase by 8,800 AF or 6% in dry years, and decrease by 41,100 AF or 7% in wet years. There would be an increase in flows on average in dry years due to additional inflow to the Colorado River from the Williams Fork River (see the section on flow changes in the Williams Fork River). The increase in Williams Fork River inflows exceeds flow reductions from additional diversions upstream. Annual flows at the gage near Kremmling would decrease by 62,600 AF or 9% on average, 4900 AF or 1% in dry years, and 87,900 AF or 7% in wet years.

Tables H-1.58, H-1.59, and H-1.60 summarize average monthly flow changes in the Colorado River below Windy Gap, Colorado River below the confluence with Williams Fork River, and near Kremmling, respectively, for average, dry, and wet conditions. Below Windy Gap, flow reductions would be highly concentrated during the months from May through July when the majority of additional diversions would occur by Denver Water and Windy Gap. Flow reductions in the remaining months would be considerably less. Average monthly flows would also increase slightly in some winter and spring months. For example, in dry years, average monthly flows below Windy Gap would increase from October through May by up to 3.5 cfs or 3%. These flow increases would be caused primarily by changes in diversions and operations at Adams Tunnel and Granby Reservoir.

Below Windy Gap, monthly average flows would decrease by a maximum of 154.7 cfs or 35% in May. In dry years, monthly average flows would decrease by a maximum of 8.2 cfs or 6% in July. In wet years, monthly average flows would decrease by a maximum of 461.8 cfs or 34% in May. Moving downstream, the Colorado River is affected by tributary inflows from the Williams Fork River, Troublesome Creek, Muddy Creek, and the Blue River, and Denver Water's diversions and operations in those basins as well as other RFFAs. Below the confluence with Williams Fork River, monthly average flows would decrease by a maximum of 135.5 cfs or 22% in May. In dry years, monthly average flows would increase by a maximum of 88.7 cfs or 47% in July. In wet years, monthly average flows would decrease by a maximum of 461.4 cfs or 27% in May. Flow increases in dry years would be due to the increase in inflow from Williams Fork River. There would also be average monthly flow increases in some months under average and wet conditions. Near Kremmling, monthly average flows would decrease by a maximum of 424.2 cfs or 18% in June. In dry years, monthly average flows would decrease by a maximum of 101.3 cfs or 9% in August. In wet years, monthly average flows would decrease by a maximum of

514.6 cfs or 16% in May. At all three locations discussed above there would be minor average monthly flow increases in some winter months under average, wet and dry conditions.

Colorado River Daily Flow Changes

Figures H-4.91 through H-4.99 show average daily hydrographs at the locations discussed above for average, dry and wet conditions.

Figures H-5.15, H-5.16, and H-5.17 present flow duration curves for the Colorado River below Windy Gap, below the confluence with Williams Fork River, and near Kremmling, respectively. As shown by the flow duration curves, flow reductions would occur at higher flow rates, which typically correspond with wet years.

Table H-6.3 shows the percentage of days from May through July that flow changes would occur below Windy Gap, below the confluence with Williams Fork River, and near Kremmling. About 37% of the time, flows would decrease up to 100 cfs below Windy Gap. Below the confluence with the Williams Fork River, flow increases and decreases ranging up to 100 cfs would occur about 26% of the time. About 33% of the time, flows would decrease up to 100 cfs near Kremmling. Flow decreases would be greatest near Kremmling below the confluence with the Blue River. Table H-6.19 summarizes maximum daily flow reductions at similar locations. The maximum daily flow reduction would occur in June and would range from 2,928 cfs below Windy Gap to 3,784 cfs near Kremmling. These large flow changes are primarily caused by changes in the timing of reservoir spills.

Figures H-6.9 shows daily flow changes below Windy Gap from October 1953 through September 1957. This figure demonstrates flow reductions that would occur in a sequence of dry years followed by a wet year. Denver Water and Windy Gap would divert additional water in the wet year following the drought, to refill additional storage at Gross Reservoir and Chimney Hollow Reservoir (the proposed action for the WGFP). Additional diversions by Denver Water and Windy Gap in 1957 would cause the peak flow of 3,274 cfs in early June to be reduced to 2,182 cfs. The reduction in flows in the year following the drought depends on many factors including the length and severity of the drought, storage contents in Denver Water's system, and the physical and legal availability of water.

The reduction in flows in the year following the drought would increase the frequency and duration of dry year conditions. The change in dry year frequency and duration was evaluated at the Colorado River below Windy Gap. Annual flows for Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives were ranked based on volume. The bottom 25th percentile was assumed to include dry and below average years. Below Windy Gap, the number of years in the bottom 25th percentile would increase by 10 years from 12 years to 22 years, as shown in Table H-15.9. The increase in frequency of dry years would be due to Denver Water's additional diversions as well as additional diversions upstream of this location due to other RFFAs including the WGFP and growth in Grand County.

This analysis also shows the duration and recurrence of back-to-back dry years will increase under the Proposed Action with RFFAs. Under Current Conditions (2006), there would be a total of 4 sets of at least 2 back-to-back dry or below average years below

Windy Gap, with the longest period being 2 years in a row. There would be 6 sets of at least 2 back-to-back dry or below average years, with the longest period being 4 years in a row at that location.

Colorado River Peak Flow Changes

The combined effect of Denver Water's additional diversions and other RFFAs would affect the magnitude, timing, frequency, and duration of peak flows along the Colorado River mainstem.

Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the peak flow for an average year and wet year at the Colorado River below Windy Gap, the Colorado River below the confluence with Williams Fork River, and the Colorado River near Kremmling gage. As shown in Table H-14.4, the magnitude of the peak flow in an average year would decrease by up to 568 cfs at the Kremmling gage. There would be little change in the timing of the peak flow (shift of 3 days later at Windy Gap, 1 day earlier below the confluence with Williams Fork River, and 4 days earlier at Kremmling). As shown in Table H-14.5, the magnitude of the wet year peak flow would decrease by 5 cfs below Windy Gap and 41 cfs at the Kremmling gage and increase by 98 cfs below the confluence with the Williams Fork River. There would be no change in the timing of the wet year peak flow at the locations evaluated.

Changes in the frequency of peak flows for difference flood recurrence intervals are discussed in the following section and in Section 4.6.3.

Colorado River Floodplain

Flows in the Colorado River reflect Denver Water's changed diversions and reservoir operations in the Fraser River, Williams Fork River, Muddy Creek, and Blue River basins. In addition, they include the effects of both the WGFP, increased municipal demand in Grand and Summit counties with RFFAs. Annual flood flows were analyzed at two places: in the vicinity of Hot Sulphur Springs, (reflecting Fraser River flow changes, the WGFP, and growth in Grand County water use), and below the confluence with the Blue River. The latter flow integrates changes in all the tributaries listed above.

In all but 5 of the 47 model years, annual flood flows for the Colorado River below Hot Sulphur Springs would be the same or lower under the Proposed Action with RFFAs than under Current Conditions (2006). However, annual peaks with recurrence intervals from approximately 9 to 23 years are slightly greater under Current Conditions (2006). This outcome is attributable to two wet years in which the timing and magnitude of Granby Reservoir spills are different, affecting the annual peak day flow. Based on this analysis it can be inferred that the floodplain extent for a specified return interval under the Proposed Action with RFFAs would be the same or smaller as the corresponding floodplain under Current Conditions (2006).

Similar conditions apply to the Colorado River below the Kremmling gage. Generally, annual peaks under the Proposed Action with RFFAs are lower than they are under Current Conditions (2006). Accordingly, the floodplain extent for a specified recurrence interval along the Colorado River would be expected to be the same or smaller than the corresponding floodplain under Current Conditions (2006). However, PACSM output showed that for some recurrence intervals above 9 years, the flood flow is greater because of the influence that Granby Reservoir spills have on the annual peak.

Muddy Creek

Muddy Creek Stream Flow

For the purpose of analyzing changes in surface water hydrology in the Muddy Creek Basin, modeled diversions and stream flows were analyzed below Wolford Mountain Reservoir.

Changes in Muddy Creek flows would be primarily due to changes in Wolford Mountain Reservoir operations. Wolford Mountain Reservoir's primary operations include releases to cover Denver Water's and Colorado Springs' substitution requirements for out-of-priority diversions when Green Mountain Reservoir does not fill, releases to cover depletions associated with contract demands, and releases for endangered fish flow requirements. The combined effects of the following actions would result in changes in Wolford Mountain Reservoir operations and flows in Muddy Creek.

1. Releases of 5,412.5 AF/yr would no longer be made from Wolford Mountain Reservoir for endangered fish in the 15-Mile Reach. This change would affect Wolford Mountain Reservoir operations, including the timing and quantity of reservoir storage and releases, and flows in Muddy Creek. Fish flow releases are typically made in the late summer or fall when flows drop below the USFWS flow recommendations. The timing and amount released depends on the type of year (average, wet, or dry). Flows below Wolford Mountain Reservoir would be less by the amount released for 10,825 Water purposes under Current Conditions (2006). However, less water would be stored during the runoff season to replace these releases, so flows during runoff would change below the reservoir due to differences in the amounts stored and the timing and quantity of spills.
2. The demand for contract water from Wolford Mountain Reservoir is anticipated to increase to about 11,100 AF/yr. This is expected to occur under Full Use of the Existing System. Additional contract demands would change the timing and quantity of reservoir storage and releases. Releases from Wolford Mountain Reservoir would be required to cover monthly depletions if they are out of priority. The specific entities that would contract for water in the future and the locations of the depletions have not been identified. Thus, PACSM was configured so that Wolford Mountain Reservoir would release to cover contract depletions during winter months (September through March) and in summer months of dry years. In addition, releases would be made in several average years depending on whether the Shoshone Power Plant rights were estimated to be calling. Of the total future contract demand, the average annual modeled release from Wolford Mountain Reservoir to meet this demand would be about 6,700 AF. Therefore, flows in Muddy Creek would increase on average primarily during winter months and in summer months of dry years compared to Current Conditions (2006). More water would be stored during the runoff season to replace these releases, so flows below the reservoir would change during runoff due to differences in the amounts stored and the timing and quantity of spills.

3. Wolford Mountain Reservoir's substitution releases for Denver Water and Colorado Springs would be affected by actions that reduce flows in the Blue River and Colorado River and increase the call on the Colorado River relative to Current Conditions (2006). The amount of water diverted out of priority by Denver Water and Colorado Springs in relation to Green Mountain Reservoir would increase under the Proposed Action with RFFAs. As a result, substitution releases from Wolford Mountain would increase in dry years to cover Denver Water's out of priority storage in Dillon Reservoir when Green Mountain Reservoir does not fill.

The majority of flow changes anticipated in Muddy Creek would be due to other RFFAs as opposed to the Proposed Action. The actions described above would combine to have the following effect on flows in Muddy Creek. As shown in Tables H-7.1 through H-7.3, average, dry and wet year annual flows in Muddy Creek below Wolford Mountain Reservoir would increase by 340 AF or less than 1%, 2,900 AF or 7 %, and decrease by 430 AF or less than 1%, respectively.

Note that there would be little change in annual flows in average and wet years because increased Wolford Mountain Reservoir releases would be offset by an increase in the amount of water stored. This has the effect of changing the timing of flows below the reservoir but would have little effect on the quantity of flow on an average annual basis. Flows below the reservoir would generally increase on average in winter months because of additional reservoir releases to meet higher contract demands and substitution requirements. Flows below the reservoir would generally decrease on average during the runoff season when more water would be stored to replace releases, spills would be reduced, and releases to meet fish flow requirements would no longer be made.

Average annual dry year flows below Wolford Mountain Reservoir would increase because additional releases to meet contract demands and substitution requirements exceed the reduction in releases to meet fish flow requirements. There would not be a corresponding increase in the amount stored to offset additional releases because Wolford Mountain Reservoir is more often limited by the available supply in dry years and would generally store the same amount under both Current Conditions (2006) and the Proposed Action with RFFAs. Table H-1.61 summarizes average monthly flows in Muddy Creek below Wolford Mountain Reservoir for average, dry, and wet conditions. Average monthly changes in flow would range from a maximum decrease of 19.9 cfs or 6% in May to a maximum increase of 12.1 cfs or 45% in January. In dry years, average monthly changes in flow would range from a maximum decrease of 32.2 cfs or 23% in August to a maximum increase of 19.4 cfs or 45% in July. In wet years, average monthly changes in flow would range from a maximum decrease of 66.0 cfs or 48% in April to a maximum increase of 41.3 cfs or 131% in March.

Muddy Creek Daily Flow Changes

Figures H-4.100 through H-4.102 show average daily hydrographs for Muddy Creek below Wolford Mountain Reservoir for average, dry and wet conditions.

Figure H-5.18 presents a flow duration curve for Muddy Creek below Wolford Mountain Reservoir. As shown by the flow duration curve, flow reductions between Current

Conditions (2006) and the Proposed Action with RFFAs would be greatest in the range of 100 cfs to 400 cfs.

Table H-6.4 shows the percentage of days flow changes would occur below Wolford Mountain Reservoir. About 73% of the time, flows would increase up to 100 cfs. Decreases in flow ranging up to 100 cfs would occur about 14% of the time. As shown in Table H-6.19, the maximum daily flow reduction below Wolford Mountain Reservoir would occur in April and would be 1,266 cfs due to changes in the timing and magnitude of spills.

Muddy Creek Peak Flow Changes

The combined effect of Denver Water's additional diversions and other RFFAs would affect the magnitude, timing, frequency, and duration of peak flows in Muddy Creek. Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the peak flow for an average year and wet year for Wolford Mountain Reservoir outflow. The magnitude of the peak flow in an average year would decrease by 31 cfs but the magnitude of the wet year peak flow would increase by 9 cfs. There would be no change in the timing of the average or wet year peak flow.

Changes in the frequency of peak flows for different flood recurrence intervals are discussed in the following section and in Section 4.6.3.

Muddy Creek Floodplain

Impacts to the Muddy Creek floodplain between Current Conditions (2006) and the Proposed Action with RFFAs would be negligible. Wolford Mountain Reservoir contents are consistently lower than under Current Conditions (2006), partly because of increased substitution releases for Denver Water and Colorado Springs and increased releases from the West Slope pool for contract deliveries. Usually, these more than offset the cessation of 10,825 Water releases that would occur under the Proposed Action with RFFAs. As a result, Wolford Mountain enters runoff with more storage space, and the amount of water bypassed or spilled is smaller. However, in the spring of wet years, both the Denver pool and the West Slope pool reach their decreed limitation under the first storage right, and only the West Slope pool is eligible to store under Wolford Mountain's refill right. At this time of year, the West Slope pool has less capacity under the Proposed Action with RFFAs than under Current Conditions (2006) because of changes in 10,825 Water releases, so more water is spilled than Current Conditions (2006). For recurrence intervals of 4.6 years and greater, annual peak flows are the same or higher by up to 2.7%. For recurrence intervals below 4.6 years, annual peak flows are generally the same or lower.

Blue River

For the purpose of analyzing changes in flows in the Blue River Basin modeled diversions and stream flows were analyzed at Roberts Tunnel, and below Dillon and Green Mountain reservoirs.

Changes in Blue River flows would be mainly due to Denver Water's additional trans-basin diversions through Roberts Tunnel and the shift in seasonal operations between Denver Water's North and South WTPs, increased depletions due to urban growth in the Blue River Basin, and changes in Dillon Reservoir and Green Mountain Reservoir operations (storage and releases). Under the Proposed Action with RFFAs, there would be a reduction in winter operations of Foothills and Marston WTPs (South System) because the Moffat WTP (North System) would operate at a minimum level of 30 mgd during the winter. More water would be kept in Dillon Reservoir during the winter months because the Moffat WTP would meet demand that would otherwise be met by Foothills and Marston WTPs under Current Conditions (2006). Summer diversions through Roberts Tunnel would generally be higher due to an overall higher level of demand that would be met under the Proposed Action with RFFAs; however, the monthly differences are more variable than in the winter. Changes in Roberts Tunnel diversions would affect the amounts stored and spilled from Dillon and Green Mountain reservoirs. For example, more water would be stored in Dillon Reservoir during the runoff season to replace Roberts Tunnel diversions, so flows below the reservoir would change due to differences in the amounts stored and the timing and magnitude of spills. Green Mountain Reservoir operations would be affected by changes in flows below Dillon Reservoir.

In addition to Denver Water's diversions, diversions associated with municipal and industrial growth in Summit County would increase by about 9,250 AF. Additional diversions in Summit County due to growth in municipal and snowmaking water demands would result in both additional depletions and changes in return flows. For example, additional snowmaking diversions would decrease flows in winter months but increase flows in summer months due to return flows.

Roberts Tunnel Diversions

As shown in Tables H-7.1 through H-7.3, average annual Roberts Tunnel diversions would increase by 32,100 AF or 46%, 23,100 AF or 18% in dry years, and 25,300 or 72% in wet years. The majority of the increase in Roberts Tunnel diversions would occur as Denver Water's average annual demand increases from Current Conditions (2006) to Full Use of the Existing System prior to implementation of the Moffat Project. Table H-1.62 summarizes average monthly diversions through the Roberts Tunnel for average, dry, and wet conditions. Diversions through Roberts Tunnel would decrease on average during the winter months and increase on average during the summer months. Denver Water's increased diversions through Roberts Tunnel would be greatest from June through October. There is less variation in the decrease in diversions during winter months than the increase in diversions in summer months. Increases in diversions in summer months would tend to be greatest in average and wet years and would depend on how system-wide storage contents, hydrologic conditions and how Denver Water's Blue River supplies are used in conjunction with their South Platte River and Moffat system supplies. Monthly average diversions would decrease up to 19.6 cfs or 27% in February and increase up to 131.9 cfs or 68% in September. In dry years, monthly average diversions would decrease up to 16.7 cfs or 23% in March and increase up to 127.9 cfs or 52% in June. In wet years, monthly average diversions would decrease up to 18.3 cfs or 37% in January and increase up to 142.5 cfs or 98% in September.

Table H-6.9 shows the percentage of days that Roberts Tunnel diversions would change. Increases in diversions from 1 to 99 cfs would be most common and occur approximately 30% of the time. The maximum daily increase in diversions would be 605 cfs in January.

Significant increases in diversions would more frequently occur in July, August, and September.

Blue River Stream Flow

Flows below Dillon Reservoir reflect differences in Roberts Tunnel diversions, Dillon Reservoir spills and additional depletions and changes in returns flows due to growth in municipal and snowmaking water demands in Summit County. Average monthly flows are lower throughout the year with the greatest reductions in flow occurring during summer months. Flow changes during the winter months are relatively minor. Average annual outflow from Dillon Reservoir would decrease by 32,500 AF or 26%, 9,000 or 18% in dry years and 31,200 AF or 13% in wet years. Table H-1.63 summarizes average monthly outflow from Dillon Reservoir for average, dry, and wet conditions. Monthly average outflow would decrease by a maximum of 253.0 cfs or 33% in June. In dry years, monthly average outflow would decrease by a maximum of 70.9 cfs or 49% in July. In wet years, monthly average outflow would decrease by a maximum of 397.9 cfs or 42% in May. The magnitude and quantity of flow reductions depends to a large extent on Dillon Reservoir spills. The number of days that Dillon Reservoir is full and spilling would be reduced by between 30 and 40%.

In several months there would be no change in flow below Dillon Reservoir because Denver Water would store all it could and bypass only what it must, which is typically 50 cfs. Although Denver Water has the ability to reduce bypass flows below Dillon Reservoir, they have not exercised that right to date. Reductions in bypass flows below Dillon Reservoir were not included in PACSM. There is no indication that reductions in Dillon Reservoir bypass flows would increase under the Proposed Action with RFFAs.

PACSM results show there would be days under Current Conditions (2006) and the Proposed Action with RFFAs when the flow below Dillon Reservoir would be less than 50 cfs (254 days under Current Conditions [2006] and 146 days under the Proposed Action with RFFAs out of 16,436 days in the 45-year study period). The number of days less than 50 cfs decreases under the Proposed Action with RFFAs because water demands for Summit County municipalities increase and more augmentation water is released from Dillon Reservoir. In addition, substitution releases from Dillon Reservoir increase in one year of the study period under the Proposed Action with RFFAs. Flows are less than 50 cfs for the following reasons. Dillon Reservoir is required to bypass from Dillon Reservoir a minimum of 50 cfs or inflow, whichever is less. On days when modeled flows are less than 50 cfs, the inflow to Dillon Reservoir is less than 50 cfs. This can occur in the model on days the natural flow at Dillon Reservoir, which is calculated based on historical USGS gage records, Roberts Tunnel flows, change in storage and evaporation at Dillon Reservoir, and upstream depletions, is very low. Very small differences in reservoir gage height readings can equate to large changes in reservoir contents, therefore, the calculated natural flow in PACSM may be lower or higher than actually occurred. This is particularly an issue on low flow days and could result in modeled inflows being less than 50 cfs when in actuality the inflow would have been higher.

Actual operations and releases from Dillon Reservoir are based on a 7-day running average to smooth out small day-to-day variations in reservoir gage height measurements and maintain a more steady flow in the Blue River below Dillon Reservoir. Operations since

1990 show that the 7-day average flow below Dillon Reservoir has rarely been below 50 cfs. This can be expected to continue in the future under Current Conditions (2006), Full Use of the Existing System and the Proposed Action with RFFAs. PACSM operates on a daily basis as opposed to a 7-day running average basis. To provide a more accurate estimate of low flow conditions below Dillon Reservoir for the analysis of resource effects, the daily flow below Dillon Reservoir was recalculated based on a 7-day running average. While this produces flow estimates that are more representative of actual operations, 7-day average flows may still be low due to the methodology used to calculated natural inflows described above.

Average annual municipal and snowmaking demands in the Blue River Basin would increase by about 9,250 AF. These demands would result in additional depletions of approximately 1,200 AF/yr on average and changes in the timing and quantity of return flows. As shown in Table 4.6.1-5, water supplies are primarily adequate to meet Current Conditions (2006) demands for water providers in the Blue River Basin, with the exception of Keystone Snake River Snowmaking. Although PACSM results indicate that Keystone Snake River Snowmaking would have an average annual shortage of 181 AF primarily during November and December due to the instream flow requirement at their diversion, it is unlikely this would occur. To address this, Keystone has been diverting water from the Roberts Tunnel via the Montezuma shaft to help meet their snowmaking demands. Because this operation has only occurred in recent years it was not included in PACSM, however, had it been, shortages would likely be reduced and possibly avoided. Under the Proposed Action with RFFAs, Summit County water providers would experience average annual shortages ranging from 1 AF to 181 AF. Water providers that would experience increased shortages compared to Current Conditions (2006) include Arapahoe Basin Snowmaking, Keystone Snake River Snowmaking, Keystone Montezuma domestic, Keystone Gulch, Snake River Water District, and Copper Mountain Water and Sanitation District. The majority of additional shortages in the Blue River Basin would occur due to Denver Water's additional diversions as their average annual demand increases from Current Conditions (2006) to Full Use of the Existing System. Tables H-13.9 through H-13.18 summarize additional shortages anticipated to occur between Current Conditions (2006) and Full Use of the Existing System for Summit County water providers. Additional shortages would occur primarily during the winter months from October through April due to Denver Water's upstream diversions and limited supplies. The shortage for Copper Mountain Water and Sanitation district would occur because their build-out demand exceeds the supply that can be provided by their existing water rights. This shortage could potentially be avoided if Copper Mountain acquired additional water rights.

Changes in Blue River flows below Green Mountain Reservoir are the result of the interaction between the seasonal shift in operations between Denver Water's northern and southern treatment systems and increased demand from Denver Water, Colorado Springs and municipalities in Summit County. The combined effect of these actions results in less water stored in Green Mountain Reservoir and a corresponding decrease in reservoir releases for power, minimum flow requirements and demand. Releases for power would be less since Green Mountain Reservoir contents would typically be lower during the winter months. Power releases are typically made from November through March to reach a target by the end of March that is dependent on the forecast. Average monthly flows are lower throughout the year with the greatest reductions in flow occurring during summer months in June and July.

Note that flows in March, which are estimated by PACSM, are higher than have historically occurred due to operating rules included in the model for Green Mountain Reservoir. In PACSM, Green Mountain Reservoir is lowered to 50,000 AF, 60,000 AF or 70,000 AF by April 1 based upon the most probable inflow conditions. While this is consistent with the U.S. Department of the Interior, Bureau of Reclamation Annual Operating Plan, it does not always match historical operations. Historical operations show that the start of fill date for Green Mountain Reservoir has varied between April 1 and May 15 because snowpack and snowmelt conditions differ from year to year (particularly in wet years). Often the start of fill data is set retroactively months afterwards. While PACSM accurately reflects Green Mountain Reservoir operations in a dry year, it is difficult to replicate the variability in operations in wet years since model operations are driven by defined operating rules and drawdown targets. PACSM results for April and May show flows are lower than have occurred historically. This is also related to the operating rules for Green Mountain and the start of fill date of April 1. The bypass requirement below Green Mountain Reservoir is 60 cfs, therefore, the flow below the reservoir is often no more than 60 cfs in PACSM after April 1 until the reservoir fills. Since the start of fill date has historically varied between April 1 and May 15, the flows below Green Mountain Reservoir are often higher than 60 cfs if the reservoir is still being drawn down to target levels. The start of fill date affects the timing of flow below Green Mountain Reservoir but has little impact on the average annual volume of flow below the reservoir. For example, a later start-of-fill date results in spills later in the season, however, the volume of water spilled would be similar regardless of the start-of-fill date.

Flow changes during the winter months are relatively minor particularly from December through March. As shown in Tables H-7.1 through H-7.3, average annual outflow from Green Mountain Reservoir would decrease by 32,900 AF or 12%, 9,600 or 5% in dry years, and 38,000 AF or 8% in wet years. Table H-1.64 summarizes average monthly outflow from Green Mountain Reservoir for average, dry, and wet conditions. Monthly average outflow would decrease by a maximum of 270.7 cfs or 30% in June. In dry years, monthly average outflow would decrease by a maximum of 59.1 cfs or 11% in July and increase by a maximum of 1.8 cfs or 1% in April. In wet years, monthly average outflow would decrease by a maximum of 215.2 cfs or 10% in June.

Blue River Daily Flow Changes

Figures H-4.103 through H-4.105 show average daily diversions through Roberts Tunnel for average, wet, and dry conditions. Figures H-4.106 through H-4.111 show average daily outflow from Dillon and Green Mountain reservoirs for average, wet, and dry conditions.

Figures H-5.19 and H-5.20 present flow duration curves for Dillon Reservoir and Green Mountain Reservoir outflow, respectively. As shown by the flow duration curves, flow reductions would typically occur at higher flow rates.

Table H-6.5 shows the percentage of days from April through October that flow changes would occur below Dillon and Green Mountain reservoirs. Below Dillon Reservoir, the flow change would be less than 1 cfs about 62% of the time from June through August when the majority of flow changes occur. Flows would decrease up to 100 cfs about 17%

of the time. Below Green Mountain Reservoir, the flow change would be less than 1 cfs about 41% of the time from June through August when the majority of flow changes occur. Flows would decrease or increase up to 100 cfs about 24% and 20% of the time, respectively. Table H-6.19 summarizes maximum daily flow reductions at similar locations. The maximum daily flow reduction would occur in June and would be 2,226 cfs below Dillon Reservoir and 3,723 cfs below Green Mountain Reservoir. These large flow decreases are primarily caused by changes in the timing and magnitude of reservoir spills.

Figure H-6.10 presents daily flow changes below Dillon Reservoir from October 1953 through September 1957. This figure demonstrates flow reductions that would occur in a sequence of dry years followed by a wet year. Denver Water would divert additional water in the wet year following the drought, to refill Dillon Reservoir and deliver water through the Roberts Tunnel for storage in its South Platte River Basin reservoirs. Additional diversions under the Proposed Action with RFFAs would reduce Dillon Reservoir contents and eliminate an early season spill in May 1957 that would occur under Current Conditions (2006). The volume spilled later in the season in August and September would be less but the peak flow would not change.

The reduction in flow in the year following the drought would increase the frequency and duration of dry year conditions. The change in dry year frequency and duration was evaluated for the Blue River below Dillon Reservoir. Annual flows for Current Conditions (2006), Full Use of the Existing System, No Action, and each of the action alternatives were ranked based on volume. The bottom 25th percentile was assumed to include dry and below average years. Below Dillon Reservoir, the number of years in the bottom 25th percentile would increase by 12 years from 12 years to 24 years, as shown in Table H-15.10. The increase in frequency of dry years would be due to Denver Water's additional diversions as well as additional diversions upstream of this location due to growth in Summit County.

This analysis also shows the duration and recurrence of back-to-back dry years will increase. Under Current Conditions (2006), there would be 4 sets of at least 2 back-to-back dry or below average years below Dillon Reservoir, with the longest period being 3 years in a row. Under the Proposed Action with RFFAs, there would be 6 sets of at least 2 back-to-back dry or below average years, with the longest period being 5 years in a row at that location.

Blue River Peak Flow Changes

The combined effect of Denver Water's additional diversions and other RFFAs would affect the magnitude, timing, frequency, and duration of peak flows in the Blue River.

Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the average peak flow for an average year and wet year for the Blue River below Dillon and Green Mountain reservoirs. The magnitude of the peak flow below Dillon Reservoir would decrease by 275 cfs and shift 10 days later in an average year. The magnitude of the peak flow below Green Mountain Reservoir would decrease by 437 cfs and shift 4 days earlier in an average year. The magnitude of the wet year peak flow below Dillon Reservoir would increase by 208 cfs and shift 8 days earlier. The magnitude of the wet year peak flow below Green Mountain Reservoir would increase by 112 cfs and shift 5 days earlier. The increase in the wet year peak flow is due primarily to the change in the timing and magnitude of spills at Dillon and Green Mountain reservoirs in the five wettest years in the study period.

Changes in the frequency of peak flows for difference flood recurrence intervals are discussed in the following section and in Section 4.6.3.

Blue River Floodplain

Below Dillon Reservoir, annual peak flows for the Proposed Action with RFFAs are equal to or lower than annual peak flows for Current Conditions (2006) at all return intervals, in which case there would be negligible impact to floodplain size. Below Green Mountain Reservoir, the same is true except at recurrence intervals greater than 9 years. Peak flows for 3 out of 5 flood events analyzed in this category were greater than for Current Conditions (2006), by 5 to 10%, indicating there would be minor increases in the size of the floodplain. The daily time series shows that peak flows could potentially be attenuated by releasing more water from Green Mountain Reservoir pre-emptively, so it is possible that there would be no change to annual peak flows.

South Boulder Creek

South Boulder Creek Stream Flow

For the purpose of analyzing changes in flows in South Boulder Creek, modeled diversions and stream flows were analyzed at the South Boulder Creek at Pinecliffe gage, below Gross Reservoir, and at the South Boulder Creek near Eldorado Springs gage. Changes along South Boulder Creek were described with respect to three different sections of the creek: (1) from the Moffat Tunnel to Gross Reservoir, (2) from Gross Reservoir to the South Boulder Diversion Canal, and (3) below the South Boulder Diversion Canal.

Changes in South Boulder Creek flows under the Proposed Action with RFFAs would be due to Denver Water's additional trans-basin diversions through Moffat Tunnel, changes in storage and releases from Gross Reservoir to meet a higher demand, and increased diversions at the South Boulder Diversion Canal. In the uppermost reach, changes in flow are equivalent to changes in Moffat Tunnel deliveries. As shown in Tables H-7.1 through H-7.3, annual flows at the Pinecliffe gage would increase by 13,000 AF or 12% on average, 1,500 or 2% in dry years, and 17,900 AF or 17% in wet years. Note, that the combination of 5 years that were averaged to determine a wet and dry year average are different for the Moffat Tunnel versus South Boulder Creek because diversions into the Moffat Tunnel occur on the West Slope, whereas South Boulder Creek is located on the East Slope. Refer to Section 4.6.1 for a discussion of West Slope versus East Slope dry and wet year averages. As a result, the changes in wet and dry year annual averages are not comparable for the Moffat Tunnel and Pinecliffe gage.

Table H-1.65 summarizes average monthly flows at the Pinecliffe gage for average, dry, and wet conditions. Flow increases would occur primarily in May, June, and July when additional diversions through Moffat Tunnel would be greatest. As discussed under the section for the Fraser River, Moffat Tunnel diversions would increase in dry years due to reductions in bypass flows in the Fraser River Basin as Denver Water's demands increase from Current Conditions (2006) to Full Use of the Existing System. As a result, flow increases would occur in South Boulder Creek above Gross Reservoir in dry years. There would also be flow decreases in South Boulder Creek in winter months due to reduced Moffat Tunnel diversions during those months compared to Current Conditions (2006). Some of the water that would be diverted through the Moffat Tunnel under Current Conditions (2006) would be diverted for snowmaking purposes in the Fraser River Basin instead because those demands would increase. Monthly average flows at the Pinecliffe gage would increase by a maximum of 119.9 cfs or 20% in June and decrease by a maximum of 1.2 cfs or 3% in November. In dry years, monthly average flows would increase by a maximum of 16 cfs or 11% in July and decrease by a maximum of 2.4 cfs or 8% in November. In wet years, monthly average flows would increase by a maximum of 175.3 cfs or 39% in June and decrease by a maximum of 2.5 cfs or 6% in November.

From Gross Reservoir to the South Boulder Diversion Canal, changes in flow reflect Gross Reservoir operations. In general, flows would be higher from October through April, as water would be moved out of Gross Reservoir and into Ralston Reservoir. The Moffat WTP would operate at a minimum of 30 mgd during the winter; therefore, more water would be released from Gross Reservoir during these months in response to the treatment load shift. In April, water would be proactively released from Gross Reservoir, in anticipation of the runoff and to stage as much water as possible close to the Moffat WTP. Releases from Gross Reservoir during a drought would depend on storage conditions in Denver Water’s North and South systems and hydrologic conditions. Increases in outflow from Gross Reservoir would be greatest in dry years because Denver Water would draw more water from their North System storage with the Proposed Action as a drought begins. In advanced stages of a drought, Denver Water’s South System reservoirs would have more water and get drawn on more intensely. Thus, changes in stream flow in August, for example, would differ depending on storage conditions in Denver Water’s North and South systems and hydrologic conditions. Flows from May through September would be lower on average because Foothills and Marston WTPs would meet a greater portion of the overall demand during these months with the Proposed Action and as a result, Gross Reservoir releases would decrease.

As shown in Tables H-7.1 through H-7.3, annual outflow from Gross Reservoir would increase by 12,300 AF or 11% on average, 17,500 AF or 21% in dry years, and 18,600 AF or 17% in wet years. Table H-1.66 summarizes average monthly outflow from Gross Reservoir for average, dry, and wet conditions. Monthly average flows would decrease up to 53.5 cfs or 20% in May and increase up to 88 cfs or 865% in January. In dry years, monthly average flows would decrease up to 44.9 cfs or 18% in July and increase up to 85.1 cfs or 1,083% in January. In wet years, monthly average flows would decrease up to 50.7 cfs or 24% in May and increase up to 84.5 cfs or 687% in January.

Below the South Boulder Diversion Canal, flows would generally decrease on average because Denver Water would divert more native South Boulder Creek water, either to storage at Gross Reservoir or under their direct diversion right at the South Boulder Diversion Canal. These additional diversions, which would occur in wet years during runoff in May and June, would reduce flows below the canal. As shown in Tables H-7.1 through H-7.3, annual flows at the Eldorado Springs gage would decrease by 1,300 AF or 3% on average, increase by 190 AF or less than 1% in dry years, and decrease by 4,800 AF or 8% in wet years. Table H-1.67 summarizes average monthly flows at the Eldorado Springs gage for average, dry, and wet conditions. Monthly average flows would decrease by a maximum of 15.3 cfs or 5% in June. Monthly average flows in wet years would decrease by a maximum of 40.8 cfs or 12% in June. Flows changes would be minimal in dry years.

South Boulder Creek Native Stream Flow

Native flows on South Boulder Creek from the East Portal of the Moffat Tunnel to Gross Reservoir are affected by Denver Water's trans-basin diversions from the Fraser and Williams Fork rivers. Table H-12.20 shows the native flow at the South Boulder Creek at Pinecliffe gage and the amount and percentage added due to additional Moffat Tunnel deliveries under Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives. Under the Proposed Action with RFFAs, the average annual Moffat Tunnel delivery to South Boulder Creek increases from 151% under Current Conditions (2006) to 181% of the native flow. The increase in flow added to this river segment is greatest during the runoff season from May through July in average and wet years. In average years, the Moffat Tunnel delivery ranges up to 426% of the native flow in September. Average monthly native flows and Moffat Tunnel deliveries are 18.0 cfs and 76.8 cfs, respectively in September. In wet years, the Moffat Tunnel delivery ranges up to 669% of the native flow in September. Average monthly flows and Moffat Tunnel deliveries are 15.9 cfs and 106.1 cfs, respectively in September in a wet year. While, the percentage of flow added to South Boulder Creek from the Moffat Tunnel is significant, the section of South Boulder Creek above Gross Reservoir has been modified to accommodate up to 1,200 cfs at the Pinecliffe gage.

South Boulder Creek Daily Flow Changes

Figures H-4.112 through H-4.120 show average daily hydrographs along South Boulder Creek for average, wet, and dry conditions.

Figures H-5.21 through H-5.23 present flow duration curves for the South Boulder Creek at Pinecliffe gage, outflow from Gross Reservoir and South Boulder Creek near Eldorado Springs gage, respectively. As shown by the flow duration curve at the Pinecliffe gage, flow increases would occur primarily at higher flow rates. The flow duration curve for Gross Reservoir outflow shows flow decreases would occur primarily at higher flow rates while flow increases would occur primarily at lower flow rates. The flow duration curve at the Eldorado Springs gage shows flow decreases would occur primarily at higher flow rates.

Table H-6.6 shows the percentage of days that flow changes would occur at the Pinecliffe gage, below Gross Reservoir, and at the Eldorado Springs gage. At the Pinecliffe gage, the flow change from May through July would be less than 1 cfs about 29% of the time. Flows would increase up to 100 cfs about 60% of the time. Below Gross Reservoir, the flow change would be less than 1 cfs about 28% of the time. Flows would decrease or increase up to 100 cfs about 20% and 47% of the time, respectively. At the Eldorado Springs gage, the flow change from May through July would be less than 1 cfs about 84% of the time. Flows would either increase or decrease up to 100 cfs about 16% of the time. Table H-6.19 summarizes maximum daily flow reductions at similar locations. The maximum daily flow reduction at the Pinecliffe gage would occur in June and would be 247 cfs. Below Gross Reservoir and at the Eldorado Springs gage, the maximum daily flow reduction would occur in May and would be 516 cfs and 526 cfs, respectively.

South Boulder Creek Peak Flow Changes

Denver Water's additional diversions through the Moffat Tunnel would affect the magnitude, timing, frequency, and duration of peak flows in South Boulder Creek. Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the peak flow for an average year and wet year at the Pinecliffe gage, below Gross Reservoir, and at the Eldorado Springs gage. At the Pinecliffe gage, the magnitude of the peak flow in an average year would increase by 128 cfs, whereas below Gross Reservoir and at the Eldorado Springs gage, the peak flow would decrease by 28 cfs and 24 cfs, respectively. The timing of the peak flow would shift 3 days later below Gross Reservoir and not change at the other locations. The magnitude of the wet year peak flow would increase by 243 cfs at the Pinecliffe gage and 69 cfs below Gross Reservoir and decrease by 25 cfs at the Eldorado Springs gage. The timing of the wet year peak flow would shift 13 days later at the Pinecliffe gage and not change at the other locations.

Changes in the frequency of peak flows for difference flood recurrence intervals are discussed in the following section and in Section 4.6.3.

South Boulder Creek Floodplain

Between the East Portal of Moffat Tunnel and Gross Reservoir, the channel has been improved to accommodate a flow of 1,200 cfs, and Denver Water operates the Moffat Tunnel such that this limit, including natural flows, is not exceeded. As a result, the only annual flood flows that increase significantly under the Proposed Action with RFFAs, relative to Current Conditions (2006), are below approximately 920 cfs. During a major, rare flood event that exceeds channel capacity, the Moffat Tunnel would not be diverting water, and there would be no increase in floodplain boundaries that could be attributed to the Moffat Project.

Gross Reservoir is currently not operated to provide flood control along South Boulder Creek and that would not change under any of the alternatives. However, an enlarged Gross Reservoir would generally be able to capture some flows that would be spilled under Current Conditions (2006). As a result, annual flood flows below Gross Reservoir would consistently be smaller than under Current Conditions (2006). For estimated recurrence intervals of 2 years or more, this reduction would be approximately 8 to 12% of the Current Conditions (2006) annual flood flow, indicating that the floodplain extent would decrease below Gross Reservoir.

In 2009, the City of Boulder completed a study of the floodplain along South Boulder Creek below Gross Reservoir beginning at Eldorado Springs. Resulting floodplain mapping has not yet been adopted by the Federal Emergency Management Agency (FEMA) for regulatory purposes but the City of Boulder already uses the new maps to issue permits for properties within the South Boulder Creek Basin. The study assumed that Gross Reservoir was full during the design storm. Given that assumption, there would be no change to the floodplain below Boulder Canyon, per the Boulder study, that can be attributed to the Moffat Project. It is possible that an enlarged Gross Reservoir would result in reductions in the floodplain size due to the ability to capture additional South Boulder Creek flows.

North Fork South Platte River

For the purpose of analyzing changes in flows in the North Fork South Platte River under the Proposed Action with RFFAs, modeled diversions and stream flows were analyzed at the North Fork South Platte River below the Geneva Creek gage, which is just downstream of where the Roberts Tunnel discharges to the river.

North Fork South Platte River Stream Flow

The changes in flow in the North Fork South Platte River would be due to the shift in seasonal operations between Denver Water's northern and southern WTPs and additional trans-basin diversions through Roberts Tunnel. Monthly average diversions through the Roberts Tunnel from November through April would be lower, which results in equivalent lower flows in the North Fork South Platte River in these months. Flows during winter months would consistently be lower by about 15 to 30% on average. Summer diversions through Roberts Tunnel would generally be higher, and consequently flows in the North Fork South Platte River would be higher on average from May through October. Flow changes at the Geneva Creek gage are slightly less than changes in diversions at the Roberts Tunnel due to transit losses.

As shown in Tables H-7.1 through H-7.3, annual flows at the Geneva Creek gage would increase by 31,000 AF or 26% on average, 35,900 AF or 24% in dry years, and 16,800 AF or 17% in wet years. The State Engineer's Office assesses a 5% transit loss on Denver Water's Roberts Tunnel deliveries to the North Fork South Platte River. The transit loss is intended to offset channel losses and evaporation losses from any additional water surface area that is caused by the delivery of water along the North Fork South Platte River from the outfall of the Roberts Tunnel to the Denver Water Intake/Conduit 20. Therefore, the average annual flows in the North Fork South Platte River are less by the 5% transit loss applied to Robert Tunnel deliveries. Table H-1.68 summarizes average monthly flows in the North Fork South Platte River below Geneva Creek gage for average, dry, and wet conditions. Monthly average flows would decrease up to 18.8 cfs or 22% in February and increase up to 127.2 cfs or 54% in September. In dry years, monthly average flows would decrease up to 14.4 cfs or 16% in March and increase up to 168.7 cfs or 50% in June. In wet years, monthly average flows would decrease up to 22.3 cfs or 26% in February and increase up to 125.1 cfs or 79% in September. Note, that the combination of 5 years that were averaged to determine a wet and dry year average are different for the Roberts Tunnel versus the North Fork South Platte River because diversions at the Roberts Tunnel occur on the West Slope, whereas the North Fork South Platte River is located on the East Slope. Refer to Section 4.6.1 for a discussion of West Slope versus East Slope dry and wet year averages.

North Fork South Platte River Native Stream Flow

Native flows on the North Fork South Platte River downstream of the East Portal of the Robert Tunnel are affected by Denver Water's trans-basin diversions from the Blue River. Table H-12.21 shows the native flow and the amount and percentage added to the North Fork South Platte River below Geneva Creek gage due to Denver Water's additional Roberts Tunnel deliveries under Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives. Under the Proposed Action with RFFAs, the average annual Roberts Tunnel delivery to the North Fork South Platte River increases from 131% under Current Conditions (2006) to 191% of the native flow. The increase in flow added to this river segment is greatest in dry years in the summer and fall. In average years, the Roberts Tunnel delivery ranges up to 632% of the native flow in September. Average monthly native flows and Roberts Tunnel deliveries are 49.5 cfs and 312.9 cfs, respectively in September. In dry years, the Roberts Tunnel delivery ranges up to 789% of the native flow in October. Average monthly native flows and Roberts Tunnel deliveries are 31.7 cfs and 250.0 cfs, respectively in October in a dry year. While, the percentage of flow added to the North Fork South Platte River from the Roberts Tunnel is significant, the river segment below the Roberts Tunnel outfall has been modified to accommodate up 680 cfs (daily average) at Grant and 980 cfs (daily average) above the confluence with the mainstem.

North Fork South Platte River Daily Flow Changes

Figures H-4.121 through H-4.123 show average daily hydrographs at the North Fork South Platte River below Geneva Creek gage for average, wet, and dry conditions.

Figure H-5.24 presents a flow duration curve for the North Fork South Platte River below Geneva Creek gage. As shown, flow increases would occur at higher flow rates, while flow decreases occur at lower flow rates.

Table H-6.7 shows the percentage of days that flow changes would occur at the Geneva Creek gage and above Pine. About 11% of the time there would be little to no flow change (less than 1 cfs) at the Geneva Creek gage. Flows would increase or decrease up to 100 cfs about 57% and 17% of the time, respectively. Flow changes above Pine would be similar to the Geneva Creek gage. Table H-6.19 summarizes maximum daily flow reductions at similar locations. The maximum daily flow reduction at the Geneva Creek gage would occur in August and would be 554 cfs. The maximum daily flow reduction above Pine would also occur in August and would be 484 cfs.

North Fork South Platte River Peak Flow Changes

Denver Water's additional diversions through the Roberts Tunnel would affect the magnitude, timing, frequency, and duration of peak flows in the North Fork South Platte River.

Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the peak flow for an average year and wet year at North Fork South Platte River below Geneva Creek gage. Below the Geneva Creek gage, the magnitude of the peak flow in an average year would increase by 102 cfs and the timing would shift two days later. The magnitude of the wet year peak flow would increase by 3 cfs but the timing would not change.

North Fork South Platte River Floodplain

Denver Water regulates Roberts Tunnel diversions in an effort to keep the average daily flow in the North Fork South Platte River below 680 cfs at Grant and below 980 cfs above the confluence with the mainstem (Yevdjerick and Simons 1966, 1967). Under the Proposed Action with RFFAs, annual peak flows at Grant for recurrence intervals of approximately 6 years and greater are all between 660 and 670 cfs. These annual flood flows reflect Roberts Tunnel delivering the maximum amount allowed by the channel capacity.

From May through October, Roberts Tunnel consistently delivers more water than Current Conditions (2006) because of the increase in Denver Water's demands. Annual peak flows range from 335 to 670 cfs under Current Conditions (2006) and from 454 to 670 cfs under the Proposed Action with RFFAs. Thus flows are virtually the same for low frequency/ high recurrence intervals, but increase by as much as 30 to 40% for high frequency/low recurrence intervals. The low recurrence flows are within the channel capacity. During a major, rare flood event that exceeds channel capacity, Roberts Tunnel would not be importing substantial amounts of water, and there would be no increase in floodplain boundaries that could be attributed to the Moffat Project.

South Platte River

South Platte River Stream Flow

For the purpose of analyzing changes in flows along the South Platte River under the Proposed Action with RFFAs, modeled diversions and stream flows were analyzed below Antero, Eleven Mile Canyon, Cheesman, and Chatfield reservoirs, and at the South Platte River at three USGS gages – Waterton, Denver, and Henderson.

Antero Reservoir to Cheesman Reservoir. In the upper South Platte River, above the confluence with the North Fork South Platte River, flows would be influenced by the combined effects of Denver Water's increased demand level and the seasonal shift in operations between the Moffat WTP and Marston and Foothills WTPs. Some of the demand that would otherwise be met by the Marston and Foothills WTPs during the winter would be met by the Moffat WTP with the Proposed Action.

On average, there would be relatively little change in flows below Antero and Eleven Mile Canyon reservoirs since these reservoirs are operated more for drought protection. Flow changes below Cheesman Reservoir would be more variable. On average, flows below Cheesman Reservoir would be lower from June through August because more water would be exchanged to Cheesman Reservoir, which would reduce outflow. More water would be stored in Cheesman Reservoir through exchanges during the summer because there would be more reusable effluent due to Denver Water's increased demand level. During other months of the year, the exchange potential is limited and the net outflow would increase because more water would be released to meet a higher level of demand.

The variability in flow changes below Cheesman Reservoir is most notable during the summer months. For instance, the difference in monthly flows below Cheesman Reservoir in August would range from a decrease of 17,200 AF to an increase of 11,000 AF. One reason the change in flows would be variable for any given summer month is that Denver Water's mode of operation changes through the course of a drought. As a drought begins, Denver Water would draw more water from their North System storage with the Proposed Action, which may reduce demand on Antero, Eleven Mile Canyon, and Cheesman reservoirs. Consequently, less water would typically be used from Denver Water's South System storage at that time. In advanced stages of a drought, Denver Water's South System reservoirs would have more water and get drawn on more intensely. Thus, changes in stream flow in August, for example, would differ depending on storage conditions in Denver Water's North and South systems and hydrologic conditions.

Denver Water has the ability to reduce bypass flows below Eleven Mile Canyon and Cheesman reservoirs. Reductions in bypass flows below Eleven Mile Canyon and Cheesman reservoirs were not included in PACSM. There is no indication that reductions in bypass flows would increase under the Proposed Action with RFFAs.

As shown in Tables H-7.1 through H-7.3, annual outflow from Antero, Eleven Mile Canyon, and Cheesman reservoirs changes by less than 700 AF or 1% on average and in wet years, and in dry years, average annual outflow increases by 610 AF (7%), 1,600 AF (2%), and 9,300 AF (7%), respectively. Tables H-1.69 through H-1.71 summarize average monthly outflow from Antero, Eleven Mile Canyon, and Cheesman reservoirs for average, dry, and wet conditions. Monthly average, wet, and dry year flow changes below Antero Reservoir would be relatively small and would range up to 7.5 cfs. Monthly average outflow from Eleven Mile Canyon Reservoir would decrease up to 3.8 cfs or 1% in July and increase up to 5 cfs or 3% in September. In dry years, monthly average outflow would decrease up to 4.6 cfs or 3% in May and increase up to 17.8 cfs or 10% in August. In wet years, monthly average outflow would decrease up to 6.5 cfs or 1% in June and increase up to 8.2 cfs or 9% in March. Average monthly outflow from Cheesman Reservoir would decrease up to 14.1 cfs or 3% in June and increase up to 20.7 cfs or 6% in May. In dry years, monthly average outflow would decrease up to 14.1 cfs or about 9% in October and increase up to 48.7 cfs or 19% in September. In wet years, average monthly outflow would decrease up to 23.3 cfs or 11% in October and increase up to 26.5 cfs or 3% in May.

<u>Cheesman Reservoir to South Platte River at Waterton Gage</u>. Denver Water's direct diversions and exchanges to Strontia Springs Reservoir and Conduit 20 would change under the Proposed Action with RFFAs primarily in response to the shift in seasonal operations between Denver Water's northern and southern WTPs, as well as the overall higher level of demand that is met with additional storage on line. As a result, South Platte River flows at the Waterton gage would decrease on average in the summer months. There would be little change in flows at Waterton gage in most winter months from September through March; however, flow increases would occasionally occur. Increases in flows would be due mainly to increased load shifting between Denver Water's WTPs. Due to the load shift, water would be moved between Strontia Springs, Chatfield, and Marston reservoirs differently with the Proposed Action. While the amount moved would be comparable to the Current Conditions (2006) scenario, the timing would change.

In the summer, Foothills and Marston WTPs would operate at higher rates with the Proposed Action because of the overall higher level of demand that would be met. Therefore, Denver Water's direct diversions at Strontia Reservoir and Conduit 20 would increase in response to higher demand. The greatest increases in direct diversions would typically occur in the months of May, June, and July. In addition, exchanges to Conduit 20 would also increase in summer months for similar reasons. Because summer diversions through Roberts Tunnel would generally be higher with the Proposed Action, more reusable effluent at the Metro Wastewater Reclamation District Plant (Metro WWTP) and the Littleton-Englewood (Bi-City) WWTP would be available for exchange. The increase in available reusable effluent combined with the increased operation of Foothills and Marston WTPs in the summer, would result in increased exchanges to Conduit 20 on average. The majority of additional exchanges would occur from April through September.

Denver Water has the ability to reduce summer minimum fish flows downstream of Strontia Springs Dam at the Old Last Chance Ditch Diversion. Reductions in summer minimum flows below Strontia Springs Dam were not included in PACSM. There is no indication that reductions in these minimum flows would increase under the Proposed Action with RFFAs.

Flows at the South Platte River at Waterton gage, which is below Strontia Springs and Conduit 20, were reviewed to evaluate changes in flows as a result of increased direct diversions and exchanges up to Conduit 20. As shown in Tables H-7.1 through H-7.3, average annual flows at the Waterton gage would decrease by 14,200 AF or 13%, 1,000 AF or 3% in dry years, and 19,200 AF or 6% in wet years. Table H-1.72 summarizes average monthly flows at the Waterton gage for average, dry, and wet conditions. Monthly average flows would decrease up to 62.4 cfs or 27% in August and increase up to 0.9 cfs or 2% in November. In dry years, monthly average flows would decrease up to 7.9 cfs or 11% in July and increase up to 3.9 cfs or 13% in November. In wet years, monthly average flows would decrease up to 73.9 cfs or 9% in July and increase up to 1.8 cfs or 3% in November.

<u>South Platte River at Waterton Gage to Denver Gage</u>. In the reach along the South Platte River between the Waterton gage and Denver gage, flows would decrease on average as compared to Current Conditions (2006); however, the reduction in flow is less at the Denver gage than at the Waterton gage. The reduction in flow decreases due to additional effluent returns at Bi-City WWTP and return flows accruing to the river from Denver Water's outdoor water usage. Under the Proposed Action with RFFAs, the average annual decrease in flow at the South Platte at Waterton gage would be approximately 14,200 AF while the average annual decrease in flow at the South Platte at Denver gage would be approximately 7,900 AF. The average annual difference in flows between the Waterton and Denver gages decreases by about 6,300 AF, which coincides closely with the net return to the South Platte River in this reach.

In addition to changes due to additional return flows in this reach, there would be slight differences in flows (approximately 1,100 AF/yr on average) between the Waterton gage and below Chatfield Reservoir due to the WTP load shift. With the Proposed Action, water would be moved between Strontia Springs, Chatfield, and Marston reservoirs differently, which would result in some flow increases and decreases between the Waterton gage and Chatfield Reservoir. The amount moved between these reservoirs would be comparable to Current Conditions (2006); however, the timing changes.

Average monthly flows below Chatfield Reservoir would increase in November, December, and January by up to 2.4 cfs. Average monthly flows in the remaining months would decrease with the greatest reductions occurring during the period from April through September when the majority of additional direct diversions and exchanges would occur. There are a number of days under Current Conditions (2006) when there is zero flow below Chatfield Reservoir. This occurs almost exclusively during the winter from November through March ranging from 23% of the time in March to 44% of the time in November under Current Conditions (2006). When Chatfield Reservoir does not have to bypass water for a senior downstream call or the call is downstream of Denver Water's gravel pits, Denver Water is able to exchange water to Chatfield Reservoir leaving no outflow. There would be a minor reduction in the number of days (less than 100 days over the entire

45-year study period) there would be no outflow from Chatfield Reservoir under the Proposed Action with RFFAs.

As shown in Tables H-7.1 through H-7.3, average annual flows below Chatfield Reservoir would decrease by 15,300 AF or 13%, 1,600 AF or 7% in dry years, and 20,700 AF or 6% in wet years. Table H-1.73 summarizes average monthly flows below Chatfield Reservoir for average, dry, and wet conditions. Monthly average flows would decrease up to 71.6 cfs or 33% in August and increase up to 2.4 cfs or 6% in November. In dry years, monthly average flows would decrease up to 21.3 cfs or 51% in August and increase up to 13.6 cfs or 77% in November. In wet years, monthly average flows would decrease up to 83.8 cfs or 10% in July and increase up to 7.6 cfs or 11% in March.

Monthly flows at the Denver gage would increase on average during the winter months from October through March. In general, flows would increase in the winter months in this reach because there are additional indoor and outdoor return flows due to increased demand and additional direct diversions and exchanges up to Strontia and Conduit 20 would be fairly minimal. The changes in flows from April through September would be more variable. On average, flows would decrease. Monthly flow increases would range up to about 3,100 AF and decreases would range up to about 8,100 AF. Increases and decreases from April through September would occur in both wet and dry years. The majority of additional direct diversions and exchanges would occur from April through September. There would also be differences throughout the year due to the load shift and associated changes in the amount of water moved between Strontia Springs, Chatfield, and Marston reservoirs.

As shown in Tables H-7.1 through H-7.3, average annual flows at the Denver gage would decrease by 7,900 AF or 3%, increase by 7,300 AF or 8% in dry years, and decrease by 12,900 AF or 2% in wet years. Table H-1.74 summarizes average monthly flows at the Denver gage for average, dry, and wet conditions. Monthly average flows would decrease up to 60.5 cfs or 15% in August and increase up to 17.1 cfs or 12% in November. In dry years, monthly average flows would decrease up to 10.3 cfs or 7% in August and increase up to 36.3 cfs or 40% in November. In wet years, monthly average flows would decrease up to 73.2 cfs or 3% in June and increase up to 18.9 cfs or 13% in December.

<u>South Platte River at Denver Gage to South Platte River at Henderson Gage</u>. In the reach along the South Platte River between the Denver gage and Henderson gage, flows would decrease on average as compared to Current Conditions (2006), however, the reduction in flow is less at the Henderson gage than at the Denver gage. Under the Proposed Action with RFFAs, the average annual decrease in flow at the South Platte at Denver gage would be approximately 7,900 AF while the average annual decrease in flow at the South Platte at Henderson gage would be approximately 2,400 AF. The average annual difference in flows between the Denver and Henderson gages decreases by about 5,500 AF. The reduction in flow decrease is due primarily to additional effluent returns at the Metro WWTP and return flows accruing to the river due to Denver Water's additional outdoor water usage.

In addition to changes in return flows, there would be an increase on average in the amount diverted through the Metro WWTP pumps for Farmer's Reservoir and Irrigation Company (FRICO) because more water is available at the Metro WWTP at times when FRICO is short of water. There would also be a decrease on average in the amount diverted from the

Metro WWTP to the non-potable project under Denver Water's junior right for the reuse project and exchanges from downstream gravel pits. However, these changes are relatively minor and are generally offsetting on an average annual basis.

Flows at the Henderson gage would increase on average from July through March. In general, flows would increase in the late summer, fall and winter months in this reach because there would be additional indoor and outdoor return flows attributable to Denver Water's and Arvada's increased demands and additional direct diversions and exchanges up to Strontia Springs Reservoir and Conduit 20 would be fairly minimal. The changes in flows from April through June are more variable for the same reasons indicated for the reach between the Waterton gage and Denver gage. During that period monthly flow increases would range up to about 7,900 AF and decreases would range up to about 29,800 AF.

As shown in Tables H-7.1 through H-7.3, average annual flows at the Henderson gage would decrease by 2,400 AF or 1%, dry year average annual flows would increase by 6,600 AF or 5%, and wet year average annual flows would decrease by 8,000 AF or 1%. Table H-1.75 summarizes average monthly flows at the Henderson gage for average, dry, and wet conditions. Monthly average flows would decrease up to 55.6 cfs or 18% in April and increase up to 23.7 cfs or 10% in January and November. In dry years, average monthly flows would decrease up to 2.4 cfs or 1% in June and increase up to 19.9 cfs or 10% in August. In wet years, monthly average flows would decrease up to 187.1 cfs or 20% in April and increase up to 41.6 cfs or 3% in July.

South Platte River Daily Flow Changes

Figures H-4.124 through H-4.135 show average daily hydrographs below Cheesman Reservoir and at the Waterton, Denver and Henderson gages for average, wet, and dry conditions.

Figures H-5.25 through H-5.30 present flow duration curves for outflow from the Antero, Eleven Mile Canyon, and Cheesman reservoirs, the South Platte River at the Waterton gage, Denver gage, and Henderson gage, respectively. As shown by the flow duration curves, flow changes would be relatively small the majority of time.

Table H-6.8 shows the percentage of days that flow changes would occur for the South Platte River locations. Flow changes would occur infrequently below Antero Reservoir. About 75% of the time there would be little to no flow change (less than 1 cfs) below Antero Reservoir. The percentage of time flow decreases up to 100 cfs would occur generally increases from upstream to downstream and would be greatest at the Henderson gage. Flow decreases up to 100 cfs would occur about 38% of the time at the Henderson gage. Flow increases up to 100 cfs would occur most frequently below Cheesman Reservoir and at the Denver gage (about 52% and 62% of the time, respectively). Table H-6.19 summarizes maximum daily flow reductions at similar locations. The maximum daily flow reductions would range from 569 cfs below Antero Reservoir up to 1,811 cfs at the Denver gage.

South Platte River Peak Flow Changes

Tables H-14.4 and H-14.5 summarize changes in the magnitude and timing of the peak flow for an average year and wet year at the Waterton gage and the Henderson gage. The magnitude of the peak flow in an average year would decrease by 42 cfs at the Waterton gage and 38 cfs at the Henderson gage. There would be no change in the timing of the peak flow. The magnitude of the wet year peak flow would decrease by 116 cfs at the Waterton gage and 76 cfs at the Henderson gage. There would be no change in the timing of the wet year peak at the Waterton gage. While the timing of the wet year peak would shift 39 days earlier at the Henderson gage, a second peak would occur later at the same time as the wet year peak flow under Current Conditions (2006).

South Platte River Floodplain

Below Cheesman Reservoir, annual peaks under the Proposed Action with RFFAs are either the same or smaller at all recurrence intervals, compared with Current Conditions (2006). For recurrence intervals greater than 6.6 years, the annual peaks are very similar. For recurrence intervals between 2.5 years and 6.6 years, annual peaks are smaller than under Current Conditions (2006) by 4 to 10%. For recurrence intervals less than 2.5 years, annual peaks are smaller than under Current Conditions (2006) by 15 to 40%. Accordingly, the effect on floodplain size is negligible.

At the Denver gage, annual flood flows are generally the same or smaller than annual flood flows for Current Conditions (2006) at the same recurrence interval. However, there are a few intervals for which flood flows are larger. For recurrence intervals above 4.2 years, the greatest increase in flood flow is 1.4% of the Current Conditions (2006) flow. Differences for lower recurrence intervals are generally +/- 5% of Current Conditions (2006) flows. Changes to the floodplain extent in this reach of the river would be minor.

4.6.1.2 Alternative 1c with Reasonably Foreseeable Future Actions

Under Alternative 1c, a new 31,300-AF reservoir would be constructed at Leyden Gulch to complement a 40,700-AF enlargement at Gross Reservoir (total size 82,511 AF). The water source for Alternative 1c would be the same as the Proposed Action with RFFAs. A portion of the additional Moffat Collection System diversions would be stored in a new Leyden Gulch Reservoir. Water stored in Gross Reservoir would be released and delivered via the South Boulder Diversion Canal to Leyden Gulch Reservoir in an effort to maintain Leyden Gulch Reservoir full. This would stage water closer to the Moffat WTP and maximize the space that would be available in Gross Reservoir for collection of Moffat Collection System supplies. Water would be released from Leyden Gulch Reservoir as needed to meet demands at Moffat WTP. In general, the majority of “new” water diverted to Gross and Leyden Gulch reservoirs would be kept in storage until a drought occurs. The additional water at Gross and Leyden Gulch reservoirs would typically only be used during a drought. Changes in surface water hydrology are very similar to the Proposed Action with RFFAs because the same amount of new storage would be added to the Moffat Collection System and the water source would be the same as the Proposed Action. Differences in hydrologic conditions compared to the Proposed Action with RFFAs would be focused at Gross Reservoir and on South Boulder Creek below Gross Reservoir. Minor changes in hydrology between the Proposed Action with RFFAs and Alternative 1c would be due to differences in evaporative losses at Gross Reservoir versus Leyden Gulch Reservoir, and the staging of water in Gross Reservoir versus Leyden Gulch Reservoir.

4.6.1.2.1 Reservoir Evaporation and Fluctuation

Williams Fork Reservoir

Changes in Williams Fork Reservoir operations, evaporation, contents, and elevations under Alternative 1c are similar to the Proposed Action with RFFAs with the following differences. Average and dry year end-of-month contents under Alternative 1c would be within 100 AF of the Proposed Action with RFFAs. Wet year end-of-month contents would be within 200 AF of the Proposed Action with RFFAs. There would be minimal to no change in water elevations between Alternative 1c and the Proposed Action with RFFAs. Differences in average monthly changes in content between Alternative 1c and the Proposed Action with RFFAs are within 1%. Accordingly, the differences in reservoir contents and elevations between Current Conditions (2006) and Alternative 1c are as described above for the Proposed Action with RFFAs.

Dillon Reservoir

Changes in Dillon Reservoir operations, evaporation, contents, and elevations under Alternative 1c are similar to the Proposed Action with RFFAs with the following differences. Average and dry year end-of-month contents under Alternative 1c are up to 500 AF lower than under the Proposed Action with RFFAs. Wet year end-of-month contents would be within 700 AF of the Proposed Action with RFFAs. This is primarily due to the fact that average annual Roberts Tunnel diversions would be about 400 AF higher on average under Alternative 1c than under the Proposed Action with RFFAs. This is mainly due to higher evaporation losses system-wide with Alternative 1c as compared to the Proposed Action with RFFAs. Differences in end-of-month water elevations between Alternatives 1c and the Proposed Action with RFFAs are less than 1 foot. Differences in average monthly content between Alternative 1c and the Proposed Action with RFFAs are within 1%. Accordingly, the differences in reservoir contents and elevations between Current Conditions (2006) and Alternative 1c are as described above for the Proposed Action with RFFAs.

Wolford Mountain Reservoir

Changes in reservoir operations, evaporation, contents, and elevations under Alternative 1c are the same as the Proposed Action with RFFAs. Differences relative to Current Conditions (2006) are the same as described for the Proposed Action with RFFAs.

Gross Reservoir

Under Alternative 1c, Gross Reservoir's volume would be approximately twice its current volume. Surface area at normal high water level would increase from approximately 418 to 651 acres. Normal high water level would increase by 75 feet.

From April through November, the annual pattern of fluctuation in level and content would be similar to that under the Proposed Action with RFFAs, but reservoir levels would be approximately 50 feet lower than for the Proposed Action with RFFAs. Gross Reservoir would be at its lowest at the end of April, generally reach its highest levels in late summer, and be drawn down through the fall and winter. Average monthly contents would be greatest at the end of July at 72,500 AF and lowest at the end of April at 41,200 AF

(Table H-1.10). In dry years, monthly contents during summer months would be lower than average because the reservoir would be drawn on more heavily during a drought. Whereas, in wet years, monthly contents during summer months would be higher than average. Monthly average, dry, and wet end-of-month reservoir elevations are shown in Table H-1.11. The maximum increase and decrease in water elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and Alternative 1c are 113 feet and 38 feet, respectively. Average annual evaporative losses would be 769 AF compared to 452 AF under Current Conditions (2006), as shown in Table H-8.1.

Leyden Gulch Reservoir

Leyden Gulch Reservoir, which does not exist currently and is therefore not part of Current Conditions (2006), would be maintained more or less at capacity except in an extended drought. Monthly average, dry, and wet end-of-month contents are approximately 28,000 to 31,000 AF or up to 3,000 AF below capacity (Table H-1.22). These averages reflect drawdowns that would occur in only a few years, which follow the designated five dry years, as drought persists. Leyden Gulch Reservoir would be completely emptied during the later stages of the critical period. Monthly average, dry, and wet end-of-month reservoir elevations are shown in Table H-1.23. Average annual evaporation at Leyden Gulch Reservoir would be 623 AF, as shown in Table H-8.1.

Antero Reservoir/Eleven Mile Canyon Reservoir/Cheesman Reservoir/Strontia Springs Reservoir/Chatfield Reservoir

Changes in Denver Water's South Platte reservoir operations, evaporation, contents, and elevations under Alternative 1c are similar to the Proposed Action with RFFAs.

4.6.1.2.2 River Segments

Fraser River

Fraser River Stream Flow

Changes in Fraser River stream flow under Alternative 1c are similar to the Proposed Action with RFFAs with the following minor differences. On average, Moffat Tunnel diversions would be approximately 200 AF/yr less under Alternative 1c than under the Proposed Action with RFFAs. Because there is little difference in Moffat Tunnel diversions under Alternative 1c compared to the Proposed Action with RFFAs, flow reductions in the Fraser River Basin would be similar to the Proposed Action with RFFAs. Average and wet year annual flow decreases in the Fraser River would be up to 100 AF and 600 AF less, respectively, under Alternative 1c than under the Proposed Action with RFFAs. Throughout the basin, differences in average monthly flows between Alternative 1c and the Proposed Action with RFFAs are within 1 to 2%. Differences in flows between Alternative 1c and the Proposed Action with RFFAs would primarily occur in June and July in wet years when Gross Reservoir or Leyden Gulch Reservoir fills. Differences in flow between these alternatives would not occur in dry years.

Fraser River Floodplain

Changes in Fraser River flood flows and floodplain extents under Alternative 1c are similar to the Proposed Action with RFFAs.

Williams Fork River

Williams Fork River Stream Flow

Changes in Williams Fork River flows under Alternative 1c are similar to the Proposed Action with RFFAs. Average annual Gumlick Tunnel diversions under Alternative 1c are virtually the same as the Proposed Action with RFFAs (Table H-7.1). As a result, reductions in flow downstream of the Gumlick Tunnel and changes in Williams Fork Reservoir outflow under Alternative 1c are essentially the same as the Proposed Action with RFFAs.

Williams Fork River Floodplain

Changes in Williams Fork River flood flows and floodplain extents under Alternative 1c are similar to the Proposed Action with RFFAs.

Colorado River

Colorado River Stream Flow

Changes in Colorado River flows under Alternative 1c are similar to the Proposed Action with RFFAs with the following minor differences. Average and wet year annual flow decreases in the Colorado River below the Windy Gap diversion would be about 100 and 500 AF less, respectively, under Alternative 1c than under the Proposed Action with RFFAs. Average and wet year annual flow decreases in the Colorado River near Kremmling would be about 200 and 300 AF less, respectively, under Alternative 1c than under the Proposed Action with RFFAs. At both locations, differences in average monthly flow between Alternatives 1c and the Proposed Action with RFFAs are within 1%.

Colorado River Floodplain

Changes in Colorado River flood flows and floodplain extents under Alternative 1c are similar to the Proposed Action with RFFAs.

Muddy Creek

Muddy Creek Stream Flow

Changes in Muddy Creek flows under Alternative 1c are the same as the Proposed Action with RFFAs.

Muddy Creek Floodplain

Changes in Muddy Creek flood flows and floodplain extents under Alternative 1c are the same as for the Proposed Action with RFFAs.

Blue River

Blue River Stream Flow

Changes in Blue River flows under Alternative 1c are similar to the Proposed Action with RFFAs with the following minor differences. Under Alternative 1c, average annual Roberts Tunnel diversions are approximately 400 AF higher than the Proposed Action with RFFAs. As a result, average annual outflow from Dillon and Green Mountain reservoirs is approximately 400 AF less under Alternative 1c than the Proposed Action with RFFAs. Differences in average monthly flow between Alternatives 1c and the Proposed Action with RFFAs are within 1%.

Blue River Floodplain

Changes in Blue River flood flows and floodplain extents under Alternative 1c are similar to the Proposed Action with RFFAs.

South Boulder Creek

South Boulder Creek Stream Flow

Changes in South Boulder Creek flows under Alternative 1c are similar to the Proposed Action with RFFAs with the following differences. Above Gross Reservoir, average and wet year annual flow increases would be 200 and 300 AF less, respectively, under Alternative 1c than under the Proposed Action with RFFAs. These flow differences coincide with differences in Moffat Tunnel diversions between Alternatives 1c and the Proposed Action with RFFAs. Differences in average monthly flows between Alternatives 1c and the Proposed Action with RFFAs are less than 1% in this reach.

From Gross Reservoir to the South Boulder Diversion Canal, differences in flow changes between Alternative 1c and the Proposed Action with RFFAs are greater because of the timing of water that would be released from Gross Reservoir for delivery to Leyden Gulch Reservoir under Alternative 1c. In general, more water would be released under Alternative 1c during summer months and less during winter months compared to the Proposed Action with RFFAs. The following changes in stream flow are based on a comparison with Current Conditions (2006). In general, under Alternative 1c, flows would be consistently higher from October through February and April, as water would be moved out of Gross Reservoir and into Leyden Gulch and Ralston reservoirs. As shown in Tables H-7.1 through H-7.3, average, dry year and wet year annual outflow from Gross Reservoir would increase by 12,400 AF or 11%, 17,000 AF or 20%, and 18,500 AF or 17%, respectively, compared to Current Conditions (2006). Table H-1.66 summarizes average monthly outflow from Gross Reservoir for average, dry, and wet conditions. Monthly average flow changes would range from a decrease of 45.2 cfs or 16% in May to an increase of 84.0 cfs or 825% in January. Monthly dry year average flow changes would range from a decrease of 52.7 cfs or 22% in July to an increase of 84.0 cfs or 1,069% in January. Monthly wet year average flow changes would range from a decrease of 47.0 cfs or 22% in May to an increase of 84.6 cfs or 688% in January.

Changes in South Boulder Creek stream flow below the South Boulder Diversion Canal under Alternative 1c are the same as the Proposed Action with RFFAs.

South Boulder Creek Floodplain

Above Gross Reservoir, annual peak flows are nearly exactly the same as the Proposed Action with RFFAs, indicating there would be no difference in floodplain size under Alternative 1c. Below Gross Reservoir, annual peak flows would be higher for recurrence intervals at or above 2.7 years, compared to Current Conditions (2006), by a few percentage points. Below this threshold, annual peaks are smaller for Alternative 1c than for Current Conditions (2006). The differences for recurrence intervals above 2.7 years would be due to operations which move water from Gross Reservoir to Leyden Gulch Reservoir. Changes to the floodplain extents under Alternative 1c would be minor.

North Fork South Platte River

North Fork South Platte River Stream Flow

Changes in the North Fork South Platte River flows under Alternative 1c are similar to the Proposed Action with RFFAs with the following minor differences. Under Alternative 1c, average annual Roberts Tunnel diversions are approximately 400 AF higher than the Proposed Action with RFFAs. As a result, average annual flow in the North Fork South Platte River is approximately 400 AF more than the Proposed Action with RFFAs. Differences in average monthly flows between Alternatives 1c and the Proposed Action with RFFAs are within 1%.

North Fork South Platte River Floodplain

Changes in North Fork South Platte River flood flows and floodplain extents under Alternative 1c are similar to the Proposed Action with RFFAs.

South Platte River

South Platte River Stream Flow

Changes in South Platte River flows under Alternative 1c are similar to the Proposed Action with RFFAs with the following minor differences. Average, dry, and wet year annual flow changes along the South Platte River would differ by up to about 400 AF compared to the Proposed Action with RFFAs. Differences in average monthly flows between Alternatives 1c and the Proposed Action with RFFAs are within 1%.

South Platte River Floodplain

Changes in South Platte River flood flows and floodplain extents under Alternative 1c are similar to the Proposed Action with RFFAs.

4.6.1.3 Alternative 8a with Reasonably Foreseeable Future Actions

Under Alternative 8a, Gross Reservoir would be expanded to approximately 93,811 AF in order to provide an additional 52,000 AF of storage. In addition, approximately 5,000 AF of gravel pit storage would be added along the South Platte River. The water source for the enlarged Gross Reservoir would be the same as the Proposed Action with RFFAs. The gravel pits would be supplied with reusable return flows diverted from the South Platte River below the Metro WWTP. Diversions would be made from the South Platte River to the gravel pit lakes to the extent that reusable effluent is available and storage space exists in the gravel pit lakes. Water stored in the gravel pit lakes would generally be used for supply in dry years. In years when the stored water is not used, water would be diverted into the pits to replace evaporative losses.

Because the volume of new storage at Gross Reservoir is 20,000 AF less than the Proposed Action with RFFAs, additional diversions from the Moffat Collection System would be less under Alternative 8a. However, changes in surface water hydrology would still be similar to the Proposed Action with RFFAs because of the manner in which Denver Water would use their additional supplies at Gross Reservoir and the gravel pits. In general, the majority of "new" water diverted to Gross Reservoir would be kept in storage until a drought occurs. The additional water at Gross Reservoir would typically only be used during a drought. Reusable water would be pumped back to the Moffat Collection System infrequently and only as needed to supplement Denver Water's Moffat supplies.

4.6.1.3.1 Reservoir Evaporation and Fluctuation

Williams Fork Reservoir

Changes in Williams Fork Reservoir operations, evaporation, contents, and elevations under Alternative 8a are similar to the Proposed Action with RFFAs with the following differences. Under Alternative 8a, the increase in Gumlick Tunnel diversions would be smaller on average than the increase under the Proposed Action with RFFAs because there is 20,000 AF less new storage at Gross Reservoir. Average annual Gumlick Tunnel diversions under Alternative 8a are approximately 280 AF less than they would be under the Proposed Action with RFFAs. There is a corresponding difference in Williams Fork Reservoir's contents: they would generally be higher under Alternative 8a than Current Conditions (2006), with average monthly differences ranging from 700 to 4,400 AF (compared with differences ranging from 500 to 4,200 AF under the Proposed Action with RFFAs). Dry year contents would be virtually the same as for the Proposed Action with RFFAs, and wet year contents would be 80 to 90 AF higher in the winter when the reservoir is slightly drawn down, but equivalent in the summer when the reservoir is full or close to full. Average monthly differences in surface elevation between Alternatives 8a and the Proposed Action with RFFAs would be less than 1 foot. Differences in average monthly content between Alternatives 8a and the Proposed Action with RFFAs are within 1%.

Dillon Reservoir

Changes in Dillon Reservoir operations, evaporation, contents, and elevations under Alternative 8a would be similar to the Proposed Action with RFFAs with the following differences. Differences between Dillon Reservoir contents for Alternative 8a and Current Conditions (2006) are similar to differences between the Proposed Action with RFFAs and Current Conditions (2006) in dry years; however, average and wet year end-of-month contents under Alternative 8a are up to 600 and 1,800 AF higher, respectively, than under the Proposed Action with RFFAs. Dillon Reservoir contents would be higher under Alternative 8a on average because Roberts Tunnel diversions would be about 500 AF/yr less on average under Alternative 8a than under the Proposed Action with RFFAs. Roberts Tunnel diversions would be less under Alternative 8a because some of Denver Water's additional demand would be directly met by reusable water pumped from the gravel pits.

Differences in end-of-month water elevations between Alternatives 8a and the Proposed Action with RFFAs are less than 1 foot. The maximum increase and decrease in reservoir elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and Alternative 8a are 13 feet and 37 feet, respectively. Differences in average monthly content between Alternatives 8a and the Proposed Action with RFFAs are within 1%.

Wolford Mountain Reservoir

Changes in reservoir operations, evaporation, contents, and water elevations under Alternative 8a are the same as the Proposed Action with RFFAs.

Gross Reservoir

Under Alternative 8a, Gross Reservoir's volume would be a little more than twice its volume as compared to Current Conditions (2006). Surface area at normal high water level would be approximately 712 acres, compared with 418 acres under Current Conditions (2006) and normal high water level would increase by approximately 92 feet.

From April through November, the annual pattern of fluctuation in level and content would be similar to that under the Proposed Action with RFFAs, but reservoir levels would be approximately 30 feet lower than for the Proposed Action with RFFAs. Gross Reservoir would be at its lowest at the end of April, generally reach its highest levels in late summer, and be drawn down through the fall and winter. Average monthly contents would be greatest at the end of June at 84,700 AF and lowest at the end of April at 52,400 AF (Table H-1.10). In dry years, monthly contents during summer months would be lower than average because the reservoir would be drawn on more heavily during a drought. Whereas, in wet years, monthly contents during summer months would be higher than average. Monthly average, dry, and wet end-of-month water elevations are shown in Table H-1.11. The maximum increase and decrease in water elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and this alternative is 130 feet and 27 feet, respectively. Average annual evaporative losses would be 858 AF compared to 991 AF under the Proposed Action with RFFAs and 452 AF under Current Conditions (2006), as shown in Table H-8.1.

Antero Reservoir/Eleven Mile Canyon Reservoir/Cheesman Reservoir/Strontia Springs Reservoir/Chatfield Reservoir

Changes in Denver Water's South Platte reservoir operations, evaporation, contents, and water elevations under Alternative 8a are similar to the Proposed Action with RFFAs.

Gravel Pit Storage

Alternative 8a includes approximately 5,000 AF of storage capacity in reclaimed gravel pits adjacent to the South Platte River. The pits would typically fill with reusable effluent from November through April when unused reusable effluent is available. The gravel pits would generally only be depleted in advanced stages of a drought. Maximum end-of-month contents under Alternative 8a would be 4,000 AF in average years, 4,600 AF in dry years, and 3,800 AF in wet years (Table H-1.25). The change in average end-of-month water elevation across the year is 14 feet (Table H-1.26). Average annual evaporative losses would be 886 AF, as shown in Table H-8.1.

In wet years, there would be less reusable effluent available because less water would be imported from the Blue River. Accordingly, average wet year contents would be lower than average contents from October through May, and slightly higher from June through September. Wet year contents are lower than average during the winter months because less reusable effluent is available for storage and higher than average in summer months because reusable effluent would only be used during droughts.

Average dry year contents of the pits are higher than average for all months except September. Dry year contents are higher than average because the five designated dry years do not coincide with later stages of droughts when water is typically released from the gravel pits for delivery to the Moffat Collection System delivery point.

4.6.1.3.2 River Segments

In general, flow changes under Alternative 8a would be very similar to the Proposed Action with RFFAs. For example, average annual flow decreases below Denver Water's diversion points in the Fraser and Williams Fork river basins would generally be about 100 AF less than under the Proposed Action with RFFAs. Similarly, differences in monthly average flow decreases would be less than 1 cfs in those river basins.

Fraser River

Fraser River Stream Flow

Because the amount of new storage (52,000 AF) added in the Moffat Collection System is 20,000 AF less under Alternative 8a than the Proposed Action with RFFAs, Moffat Tunnel diversions and reductions in Fraser River stream flow would be less under Alternative 8a. On average, Moffat Tunnel diversions would be approximately 1,100 AF/yr less under Alternative 8a than under the Proposed Action with RFFAs, which is a difference of about 1.5%. Moffat Tunnel diversions are less because a portion of the firm yield that would otherwise be provided by an enlargement of Gross Reservoir under the Proposed Action with RFFAs is provided by reusable supplies and gravel pit storage along the South Platte River under Alternative 8a.

Because there is relatively little difference in Moffat Tunnel diversions under Alternative 8a compared to the Proposed Action with RFFAs, flow reductions in the Fraser River Basin would be similar to the Proposed Action with RFFAs. The difference in average monthly flows between Alternative 8a and the Proposed Action with RFFAs is generally less than 1 cfs on tributaries to the Fraser River mainstem. The maximum difference in average monthly flows between Alternative 8a and the Proposed Action with RFFAs is 6.7 cfs in July on the Fraser River mainstem below the confluence with Crooked Creek. Flows in the Fraser River Basin under Alternative 8a are higher on average compared to the Proposed Action with RFFAs because Moffat Tunnel diversions would be less. Differences in flows between Alternative 8a and the Proposed Action with RFFAs would primarily occur in June and July in wet years when Gross Reservoir fills. Differences in flow between Alternative 8a and the Proposed Action with RFFAs would not occur in dry years.

Fraser River Floodplain

Changes in Fraser River flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs.

Williams Fork River

Williams Fork River Stream Flow

Because the amount of new storage (52,000 AF) added in the Moffat Collection System is 20,000 AF less under Alternative 8a than the Proposed Action with RFFAs, Gumlick Tunnel diversions and reductions in Williams Fork River stream flow would be less under Alternative 8a. On average, Gumlick Tunnel diversions would be approximately 280 AF/yr less under Alternative 8a than under the Proposed Action with RFFAs.

Because there is little difference in Gumlick Tunnel diversions under Alternative 8a compared to the Proposed Action with RFFAs, flow reductions in the Williams Fork River Basin would be similar to the Proposed Action with RFFAs. The difference in average monthly flows between Alternative 8a and the Proposed Action with RFFAs is less than 1 cfs on all the upper tributaries to Williams Fork River. The maximum difference in average monthly flows between Alternative 8a and the Proposed Action with RFFAs is 3.7 cfs in July below Williams Fork Reservoir. Flows in the Williams Fork River Basin under Alternative 8a are higher on average compared to the Proposed Action with RFFAs because Gumlick Tunnel diversions would be less.

Williams Fork River Floodplain

Changes in Williams Fork River flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs.

Colorado River

Colorado River Stream Flow

The amount of new storage (52,000 AF) added in the Moffat Collection System is 20,000 AF less under Alternative 8a than the Proposed Action with RFFAs; therefore, reductions in Colorado River flows would be less under Alternative 8a primarily because additional Gumlick Tunnel and Moffat Tunnel diversions would be less. The maximum difference in average monthly flows between Alternative 8a and the Proposed Action with RFFAs is 11.7 cfs in July at the Colorado River near Kremmling gage, which is a difference of less than 1%.

Colorado River Floodplain

Changes in Colorado River flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs.

Muddy Creek

Muddy Creek Stream Flow

Changes in Muddy Creek stream flow under Alternative 8a are the same as the Proposed Action with RFFAs.

Muddy Creek Floodplain

Changes in Muddy Creek flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs.

Blue River

Blue River Stream Flow

Changes in Blue River stream flow under Alternative 8a are similar to the Proposed Action with RFFAs with the following differences. Under Alternative 8a, average annual Roberts Tunnel diversions are approximately 500 AF less than the Proposed Action with RFFAs because under Alternative 8a some of the demand is met from reusable water. As a result, average annual outflow from Dillon and Green Mountain reservoirs is approximately 500 AF higher under Alternative 8a than the Proposed Action with RFFAs. Differences in average monthly flow between Alternatives 8a and the Proposed Action with RFFAs are within 1%.

Blue River Floodplain

Changes in Blue River flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs.

South Boulder Creek

South Boulder Creek Stream Flow

Increases in South Boulder Creek flows would be less under Alternative 8a because additional Moffat Tunnel diversions would be less than under the Proposed Action with RFFAs. Differences in South Boulder Creek flow increases between Alternatives 8a and the Proposed Action with RFFAs correspond with differences in Moffat Tunnel diversions. On average, Moffat Tunnel diversions would be approximately 1,100 AF/yr less under Alternative 8a than under the Proposed Action with RFFAs. As a result, average annual flows at the South Boulder Creek at Pinecliffe gage would be about 1,100 less under Alternative 8a compared to the Proposed Action with RFFAs.

Because there is little difference in Moffat Tunnel diversions under Alternative 8a compared to the Proposed Action with RFFAs, flow increases in the South Boulder Creek Basin would be similar to the Proposed Action with RFFAs. The maximum difference in average monthly flows between Alternative 8a and the Proposed Action with RFFAs is 9.0 cfs in July at the South Boulder at Pinecliffe gage. Flows in South Boulder Creek under Alternative 8a are slightly lower on average compared to the Proposed Action with RFFAs. Differences in flows between Alternative 8a and the Proposed Action with RFFAs would primarily occur in June and July in wet years when Gross Reservoir fills. Differences in flow between Alternative 8a and the Proposed Action with RFFAs would be minimal in dry years and only occur in the reach between Gross Reservoir and the South Boulder Diversion Canal.

South Boulder Creek Floodplain

Above Gross Reservoir, annual peak flows are nearly exactly the same as under the Proposed Action with RFFAs indicating there would be no difference in floodplain size under Alternative 8a, compared to Current Conditions (2006). Below Gross Reservoir, changes in South Boulder Creek flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs, however, the reduction in annual flood flows is slightly smaller than under the Proposed Action with RFFAs because this alternative includes a smaller enlargement of Gross Reservoir.

North Fork South Platte River

North Fork South Platte River Stream Flow

Changes in North Fork South Platte River flows under Alternative 8a are similar to the Proposed Action with RFFAs with the following minor differences. Under Alternative 8a, average annual Roberts Tunnel diversions are approximately 500 AF less than the Proposed Action with RFFAs. As a result, average annual flow in the North Fork South Platte River is approximately 500 AF less than the Proposed Action with RFFAs. Differences in average monthly flow between Alternatives 8a and the Proposed Action with RFFAs are within 1%.

North Fork South Platte River Floodplain

Changes in North Fork South Platte River flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs.

South Platte River

South Platte River Stream Flow

Changes in South Platte River stream flow under Alternative 8a are similar to the Proposed Action with RFFAs with the following minor differences. Average, dry, and wet year annual flow changes along the South Platte River would differ by up to about 100 AF compared to the Proposed Action with RFFAs at all locations of interest except below the Metro WWTP.

For the reach below the Metro WWTP, flows are less under Alternative 8a than the Proposed Action with RFFAs because reusable effluent would be diverted for storage in gravel pits. Average annual diversions of reusable effluent to gravel pit storage would be 2,390 AF under Alternative 8a. Average annual flow reductions at the Henderson gage would be 1,600 AF more under Alternative 8a than the Proposed Action with RFFAs. The difference in the average annual flow reduction at Henderson between Alternative 8a and the Proposed Action with RFFAs does not coincide exactly with the average annual diversions of reusable effluent under Alternative 8a because of differences in the amount pumped by the Metro WWTP pumps.

As shown in Tables H-7.1 through H-7.3, annual flows at the Henderson gage would decrease by 3,900 AF or 1% on average, increase by 4,800 AF or 4% in dry years, and decrease by 9,800 AF or 2% in wet years. Table H-1.75 summarizes average monthly flows at the South Platte River at Henderson gage for average, dry, and wet conditions. Monthly average flows would decrease up to 59.6 cfs or 20% in April and increase up to 20.4 cfs or 8% in November. In dry years, monthly average flows would decrease up to 3.5 cfs or 1% in June and increase up to 17.5 cfs or 8% in August. In wet years, monthly average flows would decrease up to 196.4 cfs or 21% in April and increase up to 41.1 cfs or 3% in July.

South Platte River Floodplain

Changes in South Platte River flood flows and floodplain extents under Alternative 8a are similar to the Proposed Action with RFFAs.

4.6.1.4 Alternative 10a with Reasonably Foreseeable Future Actions

Under Alternative 10a, Gross Reservoir would be expanded to approximately 93,811 AF in order to provide an additional 52,000 AF of storage. This is the same expansion scenario as Alternative 8a. The water source for the enlarged Gross Reservoir would be the same as the Proposed Action and Alternative 8a with RFFAs. In addition, approximately 20,000 AF of storage would be developed in the Denver Basin aquifers with an aquifer storage and recovery (ASR) system. The water source for the Denver Basin ASR system would be treated reusable return flow from the Denver Water Recycling Plant.

4.6.1.4.1 Reservoir Evaporation and Fluctuation

Changes in reservoir operations, evaporation, contents, and water elevations under Alternative 10a are similar to Alternative 8a.

4.6.1.4.2 Reservoirs and River Segments

Stream Flow

There is no difference between Alternatives 10a and 8a in the amount of additional storage at Gross Reservoir. In addition, there is little difference in the timing and quantity of diversions of reusable effluent and the manner in which Denver Water would integrate use of their reusable supplies under Alternatives 10a and 8a. The primary difference between Alternatives 8a and 10a is the location of storage for reusable supplies. Under Alternative 8a, reusable supplies would be stored in gravel pits adjacent to the South Platte River, whereas under Alternative 10a, reusable effluent would be stored in the Denver Basin aquifer via injection wells. The difference in location where reusable effluent would be stored prior to delivery to the Moffat Collection System results in almost no difference in reservoir contents and elevations, and stream flows between Alternatives 10a and 8a throughout the Colorado and South Platte river basins downstream to the Metro WWTP. There is a slight difference in the amount of reusable effluent diverted because the gravel pits included in Alternative 8a would experience evaporative losses, whereas, there would be no evaporative losses associated with reusable effluent stored in the Denver Basin aquifer. As a result, average annual diversions of reusable effluent are approximately 850 AF less under Alternative 10a (2,389 AF under Alternative 8a versus 1,540 AF under Alternative 10a). Because diversions of reusable effluent are less, the amount of reusable effluent in the South Platte River below the Metro WWTP is higher under Alternative 10a than 8a. As a result, the average annual flow at the South Platte River at Henderson gage is approximately 282,700 AF under Alternative 10a, which is approximately 600 AF higher than under Alternative 8a. Otherwise, differences in average, dry, and wet year average annual flows between Alternatives 10a and 8a are less than 100 to 200 AF at all other locations of interest. Therefore, the discussion of surface water impacts associated with Alternative 8a in Section 4.6.1.3 also applies to Alternative 10a.

Floodplain

Changes in flood flows and floodplain extents under Alternative 10a are the same as Alternative 8a, which are also similar to the Proposed Action with RFFAs.

4.6.1.5 Alternative 13a with Reasonably Foreseeable Future Actions

Under Alternative 13a, Gross Reservoir would be expanded to approximately 101,811 AF in order to provide an additional 60,000 AF of storage. In addition, approximately 3,625 AF of gravel pit storage would be added along the South Platte River. The water source for the enlarged Gross Reservoir would be the same as the Proposed Action with RFFAs. The gravel pits would be supplied with transferred agricultural water rights diverted from the South Platte River. Diversions would be made from the South Platte River to the gravel pit lakes to the extent that water is available under the transferred water rights and storage space exists in the gravel pit lakes. Water stored in the gravel pit lakes would generally be used for supply in dry years. In years when the stored water is not used, water would be diverted into the pits to replace evaporative losses.

Alternative 13a is most similar to Alternative 8a. The volume of new storage at Gross Reservoir is 8,000 AF more than Alternative 8a; therefore, diversions from the Moffat Collection System would be slightly higher under Alternative 13a. However, changes in surface water hydrology would still be similar to Alternative 8a because of the manner in which Denver Water would use their additional supplies at Gross Reservoir and the gravel pits. In general, the majority of "new" water diverted to Gross Reservoir would be kept in storage until a drought occurs. The additional water at Gross Reservoir would typically only be used during a drought. Water would be pumped back to the Moffat Collection System from the gravel pits infrequently and only as needed to supplement Denver Water's Moffat supplies.

Unlike Alternative 8a, this alternative would require the conversion of agricultural water rights to municipal or other non-irrigation uses. Therefore, impacts to removal of return flows from irrigated lands may affect water quality and quantity.

4.6.1.5.1 Reservoir Evaporation and Fluctuation

Williams Fork Reservoir

Changes in Williams Fork Reservoir operations, evaporation, contents, and elevations under Alternative 13a are similar to the Proposed Action with RFFAs. Average, dry year, and wet year average end-of-month contents under Alternative 13a would be within 500 AF of the Proposed Action with RFFAs. There would be minimal to no change in water elevations between Alternatives 13a and the Proposed Action with RFFAs. Differences in average monthly content between Alternatives 13a and the Proposed Action with RFFAs are within 1%.

Dillon Reservoir

Changes in Dillon Reservoir operations, evaporation, contents, and elevations under Alternative 13a are similar to the Proposed Action with RFFAs with the following differences. Average, dry year and wet year average end-of-month contents under Alternative 13a are up to 1,170 AF higher than under the Proposed Action with RFFAs because Roberts Tunnel diversions are lower on average under Alternative 13a than under the Proposed Action with RFFAs. Differences in end-of-month reservoir elevations between Alternative 13a and the Proposed Action with RFFAs are less than 1 foot. Differences in average monthly content between Alternative 13a and the Proposed Action with RFFAs are within 1%.

Wolford Mountain Reservoir

Changes in reservoir operations, evaporation, contents, and elevations under Alternative 13a are the same as the Proposed Action with RFFAs.

Gross Reservoir

Under Alternative 13a, Gross Reservoir's volume would be approximately 102,000 AF, or two and a half times its current volume. The surface area at normal high water level would be approximately 755 acres, compared with 418 acres and normal high water level would increase by approximately 103 feet.

From April through November, the annual pattern of fluctuation in level and content would be similar to the Proposed Action with RFFAs, but reservoir levels would be approximately 20 feet lower than for the Proposed Action with RFFAs. Average monthly contents would be greatest at the end of July at 91,800 AF and lowest at the end of April at 59,100 AF (Table H-1.10). In dry years, monthly contents during summer months would be lower than average because the reservoir would be drawn on more heavily during a drought. Whereas, in wet years, monthly contents during summer months would be higher than average. Monthly average, dry, and wet end-of-month water elevations are shown in Table H-1.11. The maximum increase and decrease in water elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and this alternative are 143 feet and 26 feet, respectively. Average annual evaporative losses would be 912 AF compared to 452 AF under Current Conditions (2006), as shown in Table H-8.1.

Antero Reservoir/Eleven Mile Canyon Reservoir/Cheesman Reservoir/Strontia Springs Reservoir/Chatfield Reservoir

Changes in reservoir operations, evaporation, contents, and elevations under Alternative 13a are almost the same as the Proposed Action with RFFAs.

Gravel Pit Storage

Alternative 13a includes approximately 3,625 AF of storage capacity in reclaimed gravel pits adjacent to the South Platte River. The pits would typically fill with agricultural water supplies during the summer months when it is available. The gravel pits would generally only be depleted in advanced stages of a drought. Maximum end-of-month contents under

Alternative 13a would be 2,700 AF in average years and 3,000 AF in dry and wet years (Table H-1.25). The change in average end-of-month surface elevation across the year is 3 feet (Table H-1.26). Average annual evaporative losses would be 656 AF, as shown in Table H-8.1.

4.6.1.5.2 River Segments

Fraser River

Fraser River Stream Flow

Changes in surface water hydrology would still be similar to the Proposed Action with RFFAs because of the manner in which Denver Water would use their additional supplies at Gross Reservoir and the gravel pits.

On average, Moffat Tunnel diversions would be approximately 500 AF/yr lower under Alternative 13a than under the Proposed Action with RFFAs. The differences in flow changes in the Fraser River Basin under Alternative 13a are commensurate with the changes in Fraser River diversions through the Moffat Tunnel. Average and wet year average annual flow decreases in the Fraser River would be up to 300 AF and 200 AF less, respectively, under Alternative 13a than under the Proposed Action with RFFAs. Throughout the basin, differences in average monthly flows between Alternative 13a and the Proposed Action with RFFAs are less than 4 cfs.

Fraser River Floodplain

Changes in Fraser River flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs.

Williams Fork River

Williams Fork River Stream Flow

On average, Gumlick Tunnel diversions would be approximately 100 AF/yr lower under Alternative 13a than under the Proposed Action with RFFAs. The differences in flow changes in the Williams Fork River Basin under Alternative 13a are commensurate with the changes in Gumlick Tunnel diversions. Average and wet year annual flow decreases in the Williams Fork River would be up to 100 AF less under Alternative 13a than the Proposed Action with RFFAs. Throughout the basin, differences in average monthly flows between Alternative 13a and the Proposed Action with RFFAs are less than 5 cfs.

Williams Fork River Floodplain

Changes in Williams Fork River flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs in the upper basin. Below Williams Fork Reservoir, flow increases from Current Conditions (2006) to Alternative 13a are similar to the increases from Current Conditions (2006) to the Proposed Action with RFFAs, for recurrence intervals above 6 years. For recurrence intervals between 2.4 and 6 years, annual peaks are also greater under Alternative 13a than Current Conditions (2006), but these differences are smaller than for the Proposed Action with RFFAs.

Colorado River

Colorado River Stream Flow

Changes in Colorado River stream flow under Alternative 13a are similar to the Proposed Action with RFFAs. Average and wet year annual flow decreases in the Colorado River below the Windy Gap diversion would be about 400 AF and 1,200 AF less, respectively, under Alternative 13a than under the Proposed Action with RFFAs. Average and wet year annual flow decreases in the Colorado River near Kremmling would be about 800 AF and 2,300 AF less, respectively, under Alternative 13a than under the Proposed Action with RFFAs. At both locations, differences in average, wet and dry monthly average flows between Alternative 13a and the Proposed Action with RFFAs are less than 30 cfs.

Colorado River Floodplain

Changes in Colorado River flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs.

Muddy Creek

Muddy Creek Stream Flow

Changes in Muddy Creek flows under Alternative 13a are the same as the Proposed Action with RFFAs.

Muddy Creek Floodplain

Changes in Muddy Creek flood flows and floodplain extents under Alternative 13a are the same as for the Proposed Action with RFFAs.

Blue River

Blue River Stream Flow

Changes in Blue River flows under Alternative 13a are similar to the Proposed Action with RFFAs with the following differences. Under Alternative 13a, average annual Roberts Tunnel diversions are approximately 300 AF less than under the Proposed Action with RFFAs. As a result, average annual outflow from Dillon and Green Mountain reservoirs is approximately 300 AF more under Alternative 13a than the Proposed Action with RFFAs. Differences in average monthly flows between Alternative 13a and the Proposed Action with RFFAs are less than 4 cfs.

Blue River Floodplain

Changes in Blue River flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs.

South Boulder Creek

South Boulder Creek Stream Flow

Changes in South Boulder Creek flows under Alternative 13a are similar to the Proposed Action with RFFAs with the following differences. Above Gross Reservoir, average and wet year annual flow increases would be 500 AF and 200 AF less, respectively, under

Alternative 13a than under the Proposed Action with RFFAs. Flow differences coincide with differences in Moffat Tunnel diversions between Alternative 13a and the Proposed Action with RFFAs. Differences in average monthly flow between Alternatives 13a and the Proposed Action with RFFAs are less than 5 cfs.

From Gross Reservoir to the South Boulder Diversion Canal, changes in flow between Alternatives 13a and the Proposed Action with RFFAs reflect Gross Reservoir operations. The annual pattern of reservoir releases would be similar to that under the Proposed Action with RFFAs. Average and wet year annual flow changes would be 400 AF less and 200 AF more, respectively, under Alternative 13a than under the Proposed Action with RFFAs. Differences in average monthly flows between Alternatives 13a and the Proposed Action with RFFAs are less than 2 cfs.

Changes in South Boulder Creek flows below the South Boulder Diversion Canal under Alternative 13a are virtually the same as the Proposed Action with RFFAs.

South Boulder Creek Floodplain

Changes in South Boulder Creek flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs. Above Gross Reservoir, annual peak flows are nearly exactly the same as under the Proposed Action with RFFAs, meaning there would be no difference in floodplain size under Alternative 13a compared to Current Conditions (2006). Below Gross Reservoir, changes in South Boulder Creek flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs with this difference; because this alternative includes a smaller enlargement of Gross Reservoir, the reduction in annual flood flows is generally slightly smaller than under the Proposed Action with RFFAs.

North Fork South Platte River

North Fork South Platte River Stream Flow

Changes in the North Fork South Platte River stream flow under Alternative 13a are similar to the Proposed Action with RFFAs with the following differences. The differences in flow changes in the North Fork South Platte River under Alternative 13a compared to the Proposed Action with RFFAs are commensurate with additional diversions through the Roberts Tunnel. Under Alternative 13a, average annual Roberts Tunnel diversions would be approximately 300 AF less than the Proposed Action with RFFAs. As a result, average annual flows in the North Fork South Platte River would be approximately 300 AF less than the Proposed Action with RFFAs. Differences in average monthly flows between Alternative 13a and the Proposed Action with RFFAs are less than 2 cfs.

North Fork South Platte River Floodplain

Changes in North Fork South Platte River flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs.

South Platte River

South Platte River Stream Flow

Changes in South Platte River stream flow under Alternative 13a are similar to the Proposed Action with RFFAs with the following differences. Average, dry, and wet year annual flow changes along the South Platte River would differ by up to about 200 AF compared to the Proposed Action with RFFAs at all locations of interest except below the Metro WWTP. Differences in average monthly flow between Alternative 13a and the Proposed Action with RFFAs are less than 2 cfs above the Metro WWTP.

Flows at the Henderson gage would increase on average in all months except April, May and June compared to Current Conditions (2006). As shown in Tables H-7.1 through H-7.3, annual flows at the Henderson gage would decrease by 950 AF or less than 1% on average, increase 7,600 AF or 6% in dry years, and decrease 5,300 AF or 1% in wet years. Monthly average flows would decrease up to 54.3 cfs or 18% in April and increase up to 24.7 cfs or 10% in January. In dry years, monthly average flows would increase up to 22.0 cfs or 11% in August. In wet years, monthly average would decrease up to 179.9 cfs or 19% in April and increase up to 54.7 cfs or 4% in July.

South Platte River Floodplain

Changes in South Platte River flood flows and floodplain extents under Alternative 13a are similar to the Proposed Action with RFFAs.

4.6.1.6 No Action Alternative with Reasonably Foreseeable Future Actions

Under the No Action Alternative with RFFAs, Denver Water would continue to operate their existing system. When full utilization of their system occurs, Denver Water's available water supply would equal their customer demand, while maintaining a 30,000-AF Strategic Water Reserve (i.e., Safety Factor). While the action alternatives would meet an additional 18,000 AF/yr of demand, the No Action Alternative would have to rely on some combination of utilizing the Strategic Water Reserve and imposing more frequent mandatory restrictions to meet additional demands during drought sequences.

It is not possible to quantitatively predict when or to what degree Denver Water would negotiate a balance of depleting the Strategic Water Reserve versus imposing mandatory restrictions. To evaluate this scenario, first a quantitative analysis using PACSM output was made to evaluate depletions of the Strategic Water Reserve, and then a qualitative analysis was made of a combination of using both the Strategic Water Reserve and imposing mandatory restrictions.

4.6.1.6.1 Depletion of Strategic Water Reserve Strategy

To determine hydrologic changes as a result of the No Action Alternative with RFFAs, use of the Strategic Water Reserve Strategy was portrayed using PACSM to provide the hydrology needed to compare the No Action Alternative with the action alternatives. In general, use of the Strategic Water Reserve creates greater hydrologic impacts than would occur if some level of restrictions were also imposed. The following sections describe in detail the hydrologic impacts of using the Strategic Water Reserve.

As described below, the No Action Alternative (Depleting the Strategic Water Reserve, no restrictions) would result in the following:

- Shortages in meeting both treated and raw water customer demands
- Depletion of the Strategic Water Reserve in droughts
- Frequent drawdown of Gross Reservoir to the minimum pool level
- Increased overall system vulnerability, reduced water supply reliability, and reduced operational flexibility
- Reduced flexibility to react to droughts and emergencies

4.6.1.6.2 Reservoir Evaporation and Fluctuation

Under the No Action Alternative, Denver Water must rely on their Strategic Water Reserve to try to meet their demand during droughts. During the 45-year study period Denver Water would need to use their Strategic Reserve in 4 years. In those years, system wide storage (active capacity in Antero, Eleven Mile Canyon, Cheesman, Dillon, and Gross reservoirs) would be less than 120,000 AF and would be drawn down to a minimum of approximately 68,400 AF by the end of the critical period. These figures are based on not imposing mandatory restrictions during a drought. Denver Water's raw water and treated customers would also experience shortages. The maximum shortages to raw water and treated demands would occur during the critical period. Based on trying to meet an unconstrained demand, Denver Water's raw water customers would be short by approximately 9,600 AF and treated water demands would be short by approximately 500 AF during the critical period.

The hydrologic changes described in the following sections are based on a comparison of the Current Conditions (2006) scenario and the No Action Alternative.

Williams Fork Reservoir

Williams Fork Reservoir contents would be higher on average under No Action than under Current Conditions (2006), primarily because of changes due to RFFAs, namely expiration of the Big Lake Ditch lease and assignment of 10,825 Water releases to other reservoirs. Reservoir contents under No Action are also slightly greater on average than under the Proposed Action with RFFAs, because Gumlick Tunnel diversions are less due to limited East Slope storage. Water that would otherwise be exported under the Proposed Action with RFFAs is stored in Williams Fork Reservoir.

Differences in average end-of-month content for the No Action Alternative compared to Current Conditions (2006) would range from 1,400 AF in May to 4,900 AF in September. The greatest difference in average end-of-month water elevation is an increase of approximately 4 feet. In dry years, Williams Fork Reservoir's contents are greater under the No Action Alternative than Current Conditions (2006) in every month. Differences range from 3,200 AF (September) to 7,900 AF (June). Differences in water elevations range from 3 to 7 feet. In wet years, Williams Fork Reservoir's contents under the No Action Alternative begin the water year higher than under Current Conditions (2006). The difference grows smaller through the winter and by end of April, contents are lower by 2,500 AF. In both scenarios, the reservoir fills by end of July, so that there is no difference, and contents remain similar through September. The largest difference in wet years is 5,300 AF, occurring in October, which corresponds to a difference of 6 feet in water elevation.

The maximum increase and decrease in reservoir elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and the No Action Alternative is 45 and 39 feet, respectively. The average annual evaporative loss would be 3,353 AF compared to 3,227 AF under Current Conditions (2006) as shown in Table H-8.1.

Dillon Reservoir

Dillon Reservoir contents under the No Action Alternative with RFFAs would almost always be lower than the content associated with Current Conditions (2006), for all months and for average, dry, and wet conditions. This is because without additional storage on line, Denver Water would rely heavily on their Blue River supplies and Strategic Water Reserve to meet a higher demand, particularly during droughts. On average and for dry years, the monthly pattern of reservoir volume is similar for No Action and Current Conditions (2006), with average content being lower for No Action. The largest difference in average end-of-month contents occurs in April, when Dillon Reservoir content would be 37,000 AF or 18% less under No Action than it would be under Current Conditions (2006) (Table H-1.4). The corresponding difference in end-of-month reservoir elevation would be a decrease of nearly 19 feet on average (Table H-1.5). The smallest difference is 16,200 AF, occurring in June and responsible for a difference of 7 feet in average reservoir elevation. In dry years, Dillon Reservoir contents are consistently lower than they would be under Current Conditions (2006), reaching a maximum in June of 51,500 AF. This difference is 27% of the average June content under Current Conditions (2006). The corresponding difference in reservoir elevation would be a decrease of 23 feet on average (Table H-1.5). In September, the difference in average elevation is even greater — 25 feet, even though the difference in September content is smaller than the difference for June. This occurs because of the non-linearity of the elevation-capacity curve. During the critical period, Dillon Reservoir would be drained to a minimum of 6,500 AF.

In wet years, Dillon Reservoir levels under the No Action Alternative would be more similar to Current Conditions (2006) than they are on average. This is particularly true during and after the runoff, when the reservoir would generally be full or nearly full. The largest average monthly difference in end-of-month contents occur in March, when Dillon Reservoir content would be 22,800 AF or 9% less than March content under Current Conditions (2006) (Table H-1.4). The corresponding difference in reservoir elevation would be a decrease of 8 feet on average (Table H-1.5).

The maximum increase and decrease in reservoir elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and the No Action Alternative are 12 and 86 feet, respectively. The average annual evaporative loss would be 5,296 AF compared to 5,847 AF under Current Conditions (2006), as shown in Table H-8.1.

Wolford Mountain Reservoir

Wolford Mountain Reservoir contents under No Action Alternative are very similar to contents under the Proposed Action with RFFAs, and the dynamics described in Section 4.6.1.1.1 are generally applicable to this scenario. On a study period average basis, average end-of-month content under No Action is less than average end-of-month content under Current Conditions (2006) for every month of the year. At the beginning of the water year, contents would be 3,300 AF lower under the No Action Alternative. The difference would increase through March due primarily to West Slope contracts, and to a lesser degree, to substitution releases. At the end of March, the difference would be 5,300 AF. Contract releases persist through May under No Action Alternative, but that effect is more than offset during the runoff as more water, on average, is put in storage under No Action Alternative than under Current Conditions (2006). By end of June, the difference in average end-of-month contents is 3,400 AF. During July, August, and September, this difference is more or less maintained because increased substitution and contract deliveries are offset by the termination of 10,825 Water releases from Wolford Mountain Reservoir. The water year ends with a difference of 3,300 AF. The difference in average end-of-month contents range from 3,100 AF or 5% in August to 5,300 AF or 10% in March. Differences in average end-of-month water elevations at Wolford Mountain Reservoir range from 2 feet to 5 feet (Table H-1.8).

In dry years, content are lower under No Action than under Current Conditions (2006) in all months. Differences in average end-of-month contents range from 800 AF in October to 5,000 AF in July. These differences correspond to changes in water elevation between 1 and 4 feet. In wet years, Wolford Mountain Reservoir contents are also always lower under No Action than under Current Conditions (2006). The greatest difference (approximately 5,200 AF) occurs at the end of March; the smallest difference (approximately 500 AF) occurs at the end of May. Changes in water elevation range from 1 to 4 feet.

The maximum increase in water elevation (averaged over the month) between No Action Alternative and Current Conditions (2006), for any month over the 45-year study period, is 1.6 feet; the maximum decrease in water elevation is 37 feet. The average annual evaporative loss would be 2,568 AF compared to 2,701 AF under Current Conditions (2006), as shown in Table H-8.1.

Gross Reservoir

The No Action Alternative is the only alternative in which Gross Reservoir has the same capacity as under Current Conditions (2006). Thus reservoir contents are similar, except for additional imports via the Moffat Tunnel, and an operational change to preserve water in Gross Reservoir in late summer and fall, in preparation to stage more water in Ralston Reservoir and meet Denver's higher demands in the spring. Starting in June or early July of average and wet years, reservoir contents are the same in the two scenarios because the reservoir is full. Under No Action, more water is delivered from the West Slope from July through October, and releases are reduced in August and September as Denver depends more heavily on Blue River water during these months. As a result, Gross Reservoir contents are generally the same or higher under No Action than under Current Conditions (2006) from August through October. Winter inflows and outflows are similar, so the difference persists until March. In the No Action Alternative, larger releases are made from March through July, such that reservoir contents drop below Current Condition (2006) levels in April, but given the additional imports during the runoff season, contents are similar by June or early July. In dry years and recovery years the pattern is the same except that the additional imports may not be enough to achieve fill, and contents for No Action may be lower than for Current Conditions (2006).

Gross Reservoir average end-of-month contents under No Action range would range from 3,800 AF higher (October) to 1,300 AF lower (June) than Current Conditions (2006). In dry years, Gross Reservoir's contents under No Action would be 6,000 AF greater on average in October, and 100 AF less in May than Current Conditions (2006). Gross Reservoir would be drained to the minimum pool more frequently under the No Action Alternative than under Current Conditions (2006) and the action alternatives. Gross Reservoir would be drained to the minimum pool in 12 years out of the 45-year study period versus only 3 years under Current Conditions (2006). In wet years, there would be little change in contents in summer months because the reservoir would be full or nearly full. Average monthly differences in contents in wet years would range from 2,300 AF greater in September to 3,900 AF less in March than Current Conditions (2006).

The maximum monthly average end-of-month water elevation change would be an increase of 12 feet in an average year, an increase of 21 feet in a dry year, and a decrease of 14 feet in a wet year (Table H-1.11). The maximum increase and decrease in water elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and the No Action Alternative would be 29 feet and 39 feet, respectively. The average annual evaporative loss would be 463 AF compared to 452 AF under Current Conditions (2006), as shown in Table H-8.1.

Antero Reservoir

Antero Reservoir contents under the No Action Alternative would be lower than contents associated with all other alternatives for all months on average. This is because without additional storage on line, Denver Water would rely more heavily on their South Platte River supplies and Strategic Water Reserve to meet a higher demand, particularly during droughts. Under the No Action Alternative, Antero Reservoir average monthly contents would be lower than Current Conditions (2006) by up to 1,200 AF.

The largest difference in average monthly end-of-month contents under the No Action Alternative occurs in December, when reservoir content would be about 1,200 AF lower than Current Conditions (2006) (Table H-1.13). In dry years, the largest difference in average monthly contents would be a decrease of 360 AF. There would be little to no change in a wet year. The maximum monthly average end-of-month water elevation change would be a decrease of about 1 foot in average and no change in dry years (Table H-1.14). The maximum increase and decrease in water elevation (averaged over the month) for any month over the 45-year study period between Current Condition (2006) and the No Action Alternative would be 3 feet and 17 feet, respectively. The average annual evaporative loss would be 3,545 AF compared to 3,671 AF under Current Condition (2006), as shown in Table H-8.1.

Eleven Mile Canyon Reservoir

Similar to Antero Reservoir, Eleven Mile Canyon Reservoir contents under the No Action Alternative with RFFAs would be lower than contents associated with all other alternatives for all months on average. This is because without additional storage on line, Denver Water would rely more heavily on their South Platte River supplies and Strategic Water Reserve to meet a higher demand, particularly during droughts.

Eleven Mile Canyon Reservoir's average end-of-month contents are lower under the No Action Alternative, as compared to Current Conditions (2006), by 3,600 to 5,200 AF. Like Antero Reservoir, Eleven Mile Canyon Reservoir is used for drought supply. Under the No Action Alternative, water would be released from Eleven Mile Canyon Reservoir earlier in dry periods because of Denver Water's higher demand. As a result, average end-of-month contents for July, August, and September would be lower by up to 3,300 AF under the No Action Alternative in dry years. There would be little to no change in a wet year.

The largest change in average end-of-month contents under the No Action Alternative would be 5,200 AF in June (Table H-1.16). In dry years, the largest difference in average end-of-month contents would be 3,300 AF in September. There would be little to no change in a wet year. The monthly average end-of-month water elevation would change by up to about 2 feet in average years and 1 foot in dry years (Table H-1.17). The maximum increase and decrease in water elevation (averaged over the month) for any month over the 45-year study period between Current Conditions (2006) and the No Action Alternative would be 0.2 feet and 19.8 feet, respectively. The average annual evaporative loss would be 5,753 AF compared to 5,950 AF under Current Conditions (2006), as shown in Table H-8.1.

Cheesman Reservoir

Similar to Antero and Eleven Mile Canyon reservoirs, Cheesman Reservoir contents under the No Action Alternative are lower than contents associated with all other alternatives, for all months on average. This is because without additional storage on line, Denver Water would rely more heavily on their South Platte River supplies and Strategic Water Reserve to meet a higher demand, particularly during droughts.

Cheesman Reservoir's average end-of-month contents would be lower under the No Action Alternative as compared to Current Conditions (2006) by 500 to 3,700 AF. Under the No Action Alternative, Cheesman Reservoir would be used more heavily particularly in dry years because of Denver Water's higher demand. Cheesman Reservoir storage would be depleted more frequently under the No Action Alternative than under Current Conditions (2006) and the action alternatives.

The largest decrease in average end-of-month contents under the No Action Alternative would be 3,700 AF in May (Table H-1.19). In dry years, average end-of-month contents would be up to 7,600 AF lower in September. In wet years, reservoir contents would be slightly higher under No Action than under Current Conditions (2006), in all months except June and July when the reservoir would be full in both scenarios. The maximum monthly average end-of-month reservoir elevation decrease would be 8 feet in average years, and 20 feet in dry years (Table H-1.20). The maximum increase and decrease in water elevation (averaged over the month) for any month over the 45-year study period between

Current Conditions (2006) and the No Action Alternative would be 19 feet and 107 feet, respectively. The average annual evaporative loss would be 1,053 AF compared to 1,081 AF under Current Conditions (2006), as shown in Table H-8.1.

Strontia Springs Reservoir

Changes in reservoir operations, contents, and elevations under No Action are similar to the Proposed Action with RFFAs. Because winter demand is met by Foothills Treatment Plant under No Action, average end-of-month contents are lower than for the Proposed Action with RFFAs, by 100 to 200 AF, from October through April. The maximum average monthly difference in contents from Current Conditions (2006) is approximately 790 AF in April. From May through September, contents are lower than under Current Conditions (2006), but not quite as low as under the Proposed Action with RFFAs.

Chatfield Reservoir

Changes in reservoir operations, contents, and water elevations under No Action Alternative are generally similar to the Proposed Action with RFFAs. Winter drawdowns under No Action are slightly less pronounced than under Proposed Action with RFFAs on average. Accordingly, the maximum difference in average monthly content, relative to Current Conditions (2006) is greater for No Action Alternative than for the Proposed Action with RFFAs by several hundred acre-feet in an average, dry, and wet year.

4.6.1.6.3 River Segments

Fraser River

Changes in Fraser River flows under the No Action Alternative are directly related to the increase in Moffat Tunnel diversions, which would occur under a higher demand and other RFFAs including growth in Grand County water demands. Denver Water's average annual demand would increase from 285,000 AF under Current Conditions (2006) to 363,000 AF/yr under the No Action Alternative. Refer to Section 4.6.1.1.2 for a discussion of flow reductions and shortages in the Fraser River Basin related to other RFFAs since they would be similar to the Proposed Action with RFFAs.

Bypass Flow Reductions

The modeled reductions in minimum bypass flows in the Fraser River Basin under the No Action Alternative are the same as under Full Use of the Existing System and the Proposed Action with RFFAs because the No Action Alternative portrayed in PACSM includes use of the Strategic Water Reserve without imposing restrictions. Refer to Section 4.6.1.1.2 for a description of bypass flow reductions under Full Use of the Existing System and the Proposed Action with RFFAs.

Additional diversions under the No Action Alternative would result in more days that flows would be reduced to minimum summer bypass requirements. In addition, tributaries without bypass requirements would be dried up for a longer duration. On average, flows would be reduced to minimum summer bypass requirements at the Fraser River at Winter Park gage and below Denver Water's diversions from St. Louis Creek, Vasquez Creek, and Ranch Creek as a result of additional diversions approximately 4 more days a year and a maximum of about 20 more days in one year. On tributaries that do not have bypass requirements flows would be reduced to 0 cfs as a result of additional diversions during the summer approximately 4 more days a year on average and a maximum of about 17 more days in one year. These flow reductions would generally occur primarily in June, and May and July to a lesser degree in wet years.

As discussed under the qualitative assessment of the combination of using mandatory restrictions in addition to depleting the Strategic Water Reserve in Section 4.6.1.6.1, Denver Water can be expected to reduce minimum bypass flows on eastern and western slope streams as demand increases beyond existing supplies and restrictions are imposed. As a result, stream flows would decrease due to decreased bypass flows beyond what is reflected in PACSM.

Moffat Tunnel Diversions

Additional Moffat Tunnel diversions under the No Action Alternative would be considerably less than under the action alternatives without additional storage on line. As shown in Tables H-7.1 through H-7.3, annual Moffat Tunnel diversions would increase by 5,000 AF or 8% on average, 2,000 AF or 4% in dry years and 8,400 AF or 15% in wet years. Diversions would increase in 41 years out of the 45-year study period and additional diversions would range up to 8,500 AF in one month and 11,800 AF in one year. Table H-1.28 summarizes average monthly diversions through the Moffat Tunnel for average, dry, and wet conditions. Additional diversions through Moffat Tunnel occur primarily in May, June and July. There would be virtually no additional diversions from late summer through early spring except in infrequent, very wet years. The maximum monthly average increase in diversions would occur in June, with a 36.7 cfs or 11% increase. In dry years, the maximum monthly average increase in diversions would occur in July, with a 21.1 cfs or 23% increase. In wet years, the maximum monthly average increase in diversions would occur in June, with a 42.9 cfs or 29% increase.

Fraser River Mainstem Stream Flow

Below Denver Water's mainstem Fraser River Diversion, annual flows would decrease by 770 AF or 15% on average, 270 AF or 11% in dry years and 1,300 AF or 12% in wet years. Monthly average flows would decrease by a maximum of 8.7 cfs or 21% in June (Table H-1.29). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 23% in July. In wet years, monthly average flows would decrease by a maximum of 10.6 cfs or 11% in June. At the Fraser River at Winter Park gage, which is located downstream of Denver Water's mainstem Fraser River Diversion and their tributary diversions from Jim Creek, Cub Creek, Buck Creek, and Cooper Creek, annual flows would decrease by 1,100 AF or 13% on average, 290 AF or 7% in dry years and 2,000 AF or 12% in wet years. Monthly average flows would decrease by a maximum of 12.4 cfs or 21% in June (Table H-1.33). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 17% in June and July. In wet years, monthly average flows would decrease by a maximum of 18.7 cfs or 14% in June.

Continuing downstream, the Fraser River would be affected by Denver Water's diversions from Vasquez, St. Louis, and Ranch creeks as well as additional diversions to meet increased demands for water providers in the Fraser River Basin. Below the confluence with Vasquez Creek, average annual flows would decrease by 4,700 AF or 23% on average, 3,000 AF or 34% in dry year and 6,400 AF or 17% in wet years. Monthly average flows would decrease by a maximum of 26.6 cfs or 19% in June (H-1.38). In dry years, monthly average flows would decrease by a maximum of 7.7 cfs or 36% in June and 39% in July. In wet years, monthly average flows would decrease by a maximum of 35.7 cfs or 12% in June.

Below the confluence with St. Louis Creek, annual flows would decrease by 8,500 AF or 22% on average, 6,100 AF or 42% in dry years, and 11,200 AF or 15% in wet years. Monthly average flows would decrease by a maximum of 37.2 cfs or 15% in June (Table H-1.44). In dry years, monthly average flows would decrease by a maximum of 13.8 cfs or 53% in July. In wet years, monthly average flows would decrease by a maximum of 47.5 cfs or 8% in June.

Below the confluence with Crooked Creek, which is located below all of Denver Water's Fraser River Basin diversions, annual flows would decrease by 4,600 AF or 5% on average, 1,500 AF or 4% in dry years and 7,900 AF or 5% in wet years. Monthly average flows would decrease by a maximum of 35.8 cfs or 7% in June (Table H-1.49). In dry years, monthly average flows would decrease by a maximum of 7.9 cfs or 9% in June. In wet years, monthly average flows would decrease by a maximum of 45.5 cfs or 4% in June.

At the Fraser River at Granby gage, which is located close to the confluence with the Colorado River, annual flows would decrease by 4,900 AF or 5% on average, 1,900 AF or 5% in dry years and 8,300 AF or 5% in wet years. Monthly average flows would decrease by a maximum of 36.7 cfs or 7% in June (Table H-1.50). In dry years, monthly average flows would decrease by a maximum of 8.9 cfs or 10% in June and 16% in July. In wet years, monthly average flows would decrease by a maximum of 46.3 cfs or 4% in June.

Jim Creek Stream Flow

Below Denver Water's Jim Creek Diversion, annual flows would decrease by 230 AF or 28% on average and 530 AF or 20% in wet years. Changes in flow in a dry year would be minimal. Monthly average flows would decrease by a maximum of 3.0 cfs or 29% in June (Table H-1.30). In wet years, monthly average flows would decrease by a maximum of 6.5 cfs or 21% in June.

Cub and Buck Creeks Stream Flow

Below Denver Water's diversions from Cub and Buck creeks, annual flows would decrease by 40 AF or 15% on average and 100 AF or 15% in wet years. There would be no change in flows in a dry year. Monthly average flows would decrease by a maximum of 0.6 cfs or 25% in June (Table H-1.31). In wet years, monthly average flows would decrease by a maximum of 1.2 cfs or 17% in June.

Cooper Creek Stream Flow

Below Denver Water's diversion from Cooper Creek, annual flows would decrease by 20 AF or 23% on average and 40 AF or 34% in wet years. Changes in flow in a dry year would be insignificant. Monthly average flows would decrease by a maximum of 0.2 cfs or 31% in June (Table H-1.32). In wet years, monthly average flows would decrease by a maximum of 0.5 cfs or 41% in June.

Vasquez Creek and Tributaries Stream Flow

Below Denver Water's diversion from Vasquez Creek, annual flows would decrease by 830 AF or 10% on average, 160 AF or 5% in dry years, and 1,600 AF or 10% in wet years. Monthly average flows would decrease by a maximum of 7.8 cfs or 14% in June (Table H-1.35). In dry years, monthly average flows would decrease by a maximum of 1.3 cfs or 17% in June and July. In wet years, monthly average flows would decrease by a maximum of 9.5 cfs or 7% in June.

Below Denver Water's diversion from Little Vasquez Creek, annual flows would decrease by 160 AF or 26% on average and 350 AF or 34% in wet years. Changes in flow in a dry year would be minimal. Monthly average flows would decrease by a maximum of 1.5 cfs or 21% in June (Table H-1.36). In wet years, monthly average flows would decrease by a maximum of 2.6 cfs or 23% in June.

At the Vasquez Creek gage, annual flows would decrease by 3,700 AF or 35% on average, 2,800 AF or 67% in dry years and 4,500 AF or 23% in wet years. Monthly average flows would decrease by a maximum of 14.3 cfs or 19% in June (Table H-1.37). In dry years, monthly average flows would decrease by a maximum of 6.2 cfs or 56% in June and 62% in July. In wet years, monthly average flows would decrease by a maximum of 17.1 cfs or 11% in June.

Elk Creek and Tributaries Stream Flow

Below Denver Water's diversions from Elk Creek, West and East Elk creeks, and the East and West forks of main Elk Creek, annual flows would decrease by 90 AF or 10% on average and 200 AF or 11% in wet years. There would be no change in flows in a dry year. Monthly average flows would decrease by a maximum of 0.9 cfs or 11% in June (Table H-1.39). In wet years, monthly average flows would decrease by a maximum of 1.7 cfs or 10% in June.

St. Louis Creek and Tributaries Stream Flow

Below Denver Water's diversion from St. Louis Creek, annual flows would decrease by 430 AF or 7% on average, 240 AF or 8% in dry years and 800 AF or 7% in wet years. Monthly average flows would decrease by a maximum of 2.9 cfs or 13% in July (Table H-1.40). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 17% in June. In wet years, monthly average flows would decrease by a maximum of 4.2 cfs or 8% in July.

Below Denver Water's diversion from tributaries to St. Louis Creek including West and East St. Louis creeks, Short Creek, Byers Creek, Iron Creek, and Fool Creek, annual flows would decrease by 410 AF or 15% on average, and 900 AF or 12% in wet years. There would be no change in flows in a dry year. Monthly average flows would decrease by a maximum of 3.1 cfs or 11% in June (Table H-1.41). In wet years, monthly average flows would decrease by a maximum of 4.1 cfs or 6% in June.

Below Denver Water's diversion from King Creek, annual flows would decrease by 20 AF or 16% on average and 50 AF or 14% in wet years. Monthly average flows would decrease by a maximum of 0.2 cfs or 14% in June (Table H-1.43). There would be no change in flows in a dry year. In wet years, monthly average flows would decrease by a maximum of 0.3 cfs or 11% in June.

At the St. Louis Creek gage, average annual flows would decrease by 840 AF or 5%, 240 AF or 3% in dry years, and 1,700 AF or 6% in wet years. Monthly average flows would decrease by a maximum of 5.5 cfs or 6% in June (Table H-1.42). In dry years, monthly average flows would decrease by a maximum of 1.6 cfs or 6% in June. In wet years, monthly average flows would decrease by a maximum of 7.7 cfs or 7% in July.

Ranch Creek and Tributaries

Downstream of Denver Water's Englewood Ranch Gravity System, which includes diversions from North and South Trail Creek, Hurd Creek, Hamilton Creek, Cabin Creek, and Little Cabin Creek, annual flows would decrease by 150 AF or 2% on average and 330 AF or 3% in wet years. Flow changes in a dry year would be minimal. Monthly average flows would decrease by a maximum of 1.1 cfs or 7% in July (Table H-1.45). In wet years, monthly average flows would decrease by a maximum of 2.9 cfs or 11% in May.

Below Denver Water's North Fork Ranch Creek and Dribble Creek diversions, annual flows would decrease by 120 AF or 8% on average, 20 AF or 17% in dry years, and 210 AF or 6% in wet years. Monthly average flows would decrease by a maximum of 0.7 cfs or 13% in July (Table H-1.46). In dry years, monthly average flows would increase by a maximum of 0.2 cfs or 19% in June. In wet years, monthly average flows would decrease by a maximum of 1.9 cfs or 30% in May.

Below Denver Water's Main Ranch Creek Diversion, annual flows would decrease by 130 AF or 5% on average, 80 AF or 6% in dry years, and 180 AF or 3% in wet years. Monthly average flows would decrease by a maximum of 0.8 cfs or 4% in June and 9% in July (Table H-1.47). In dry years, monthly average flows would decrease by a maximum of 0.6 cfs or 14% in June. In wet years, monthly average flows would decrease by a maximum of 1.9 cfs or 20% in May.

Downstream of Denver Water's Middle and South Fork of Ranch Creek diversions, annual flows would decrease by 260 AF or 11% on average and 430 AF or 7% in wet years. There would be no change in flows in a dry year. Monthly average flows would decrease by a maximum of 1.5 cfs or 6% in June and 17% in July (Table H-1.48). In wet years, monthly average flows would decrease by a maximum of 3.4 cfs or 32% in May.

Fraser River Native Stream Flows

Tables H-12.1 through H-12.5 and H-12.7 through H-12.15 show the native flow and the amount and percent diverted at Denver Water's diversions in the Fraser River Basin under Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives. Additional native flow diversions under the No Action Alternative are similar to the action alternatives in timing. Additional native flow diversions under the No Action Alternative would be less than under the action alternatives because there would be no additional storage in the Moffat Collection System. Under No Action, the average annual percentage of native flow diverted would range from 21% at the Englewood Ranch Gravity System up to 92% at Denver Water's Jim Creek Diversion, which is very similar to the Proposed Action with RFFAs. In general the average annual percentage of native flow diverted by Denver Water would increase by about 4% compared to Current Conditions (2006). There would be little to no increase in the percentage of native flow diverted in winter months. The increase in the percentage of native flow diverted would be greatest in

June at almost all locations in the Fraser River Basin. In June, the average annual percentage of native flow diverted under the No Action Alternative would increase by about 3% to 8% compared to Current Conditions (2006) at most locations with a maximum increase of 8% at Denver Water's Fraser River diversion.

Table H-12.6 shows the native flow and the amount and percentage added to Vasquez Creek due to Denver Water's additional diversions from the Williams Fork River Basin, which are delivered to Vasquez Creek via the Gumlick and Vasquez tunnels. The increase in flows below the Vasquez Tunnel outfall and Denver Water's diversion from Vasquez Creek would be greatest in May and June in dry years. In June, the average monthly flow in a dry year would increase by 71.7 cfs from 16.8 cfs to 88.4 cfs.

Fraser River Daily Flow Changes

As shown by the flow duration curves (Figures H-5.1 through H-5.11), flow reductions resulting from the No Action Alternative would occur at higher flow rates, which typically correspond with wet years.

The percentage of days that flow decreases would occur compared to Current Conditions (2006) is similar to the action alternatives, however, the percentage of time that there would be little to no change in flow (less than 1 cfs) would be higher under the No Action. There would be little to no change over 76% of the time at all locations evaluated in the Fraser River Basin (Table H-6.1). As shown in Table H-6.19, the maximum daily flow reduction at the locations evaluated would be less under the No Action Alternative compared to the action alternatives.

Fraser River Floodplain

Floodplain extents in the Fraser River Basin under No Action are generally similar to Current Conditions (2006). Annual peak flows under the No Action Alternative are very similar to annual peaks under Current Conditions (2006) for high flow, low frequency events (recurrence greater than or equal to 10 years), and similar to or smaller for all other events. On Ranch Creek and St. Louis Creek, peak flows are virtually the same for all recurrence intervals of two years or more, so there would be no significant change to floodplains on these tributaries. On the mainstem, annual peaks for recurrence intervals from 2 to 10 years are reduced relative to Current Conditions (2006), but the reduction is smaller than for the Proposed Action with RFFAs.

Williams Fork River

Changes in Williams Fork River flows under the No Action Alternative are directly related to the increase in Gumlick Tunnel diversions which would occur under a higher demand and other RFFAs in the Williams Fork River Basin. Refer to Section 4.6.1.1.2 for a discussion of flow changes in the Williams Fork River Basin related to other RFFAs since they would be similar to the Proposed Action with RFFAs.

Gumlick Tunnel Diversions

Additional Gumlick Tunnel diversions under the No Action Alternative would be less than under the action alternatives without additional storage on line. As shown in Tables H-7.1 through H-7.3, annual Gumlick Tunnel diversions would increase by 1,300 AF or 15% on average, 1,300 AF or 14% in dry years and 1,200 AF or 18% in wet years. The maximum monthly and annual increase in diversions would be 3,600 AF. Table H-1.51 summarizes average monthly diversions through the Gumlick Tunnel for average, dry, and wet conditions. Additional diversions would occur primarily in May, June, and July. There would be virtually no additional diversions from late summer through early spring except in infrequent, very wet years. The maximum monthly average increase in diversions would occur in July, with a 14.0 cfs or 72% increase. In wet years, the maximum monthly average increase in diversions would occur in May, with a 7.3 cfs or 39% increase on average.

Williams Fork River Mainstem and Tributaries Stream Flow

Below Denver Water's Steelman Creek Diversion, annual flows would decrease by 330 AF or 16% on average, 330 AF or 82% in dry years and 280 AF or 7% in wet years. At this location, monthly average flows would decrease by a maximum of 3.5 cfs or 31% in July (Table H-1.52). In dry years, monthly average flows would decrease by a maximum of 4.0 cfs or 84% in July. In wet years, monthly average flows would decrease by a maximum of 2.1 cfs or 31% in May.

Below Denver Water's Bobtail Creek Diversion, annual flows would decrease by 570 AF or 16% on average, AF or 590 AF 90% in dry years and 570 AF or 7% in wet years. At this location, monthly average flows would decrease by a maximum of 6.2 cfs or 32% in July (Table H-1.53). In dry years, monthly average flows would decrease by a maximum of 8.1 cfs or 89% in July. In wet years, monthly average flows would decrease by a maximum of 2.9 cfs or 39% in May.

Below Denver Water's Jones Creek Diversion, annual flows would decrease by 180 AF or 16% on average, 180 AF or 78% in dry years and 150 AF or 6% in wet years. At this location, monthly average flows would decrease by a maximum of 2.1 cfs or 32% in July (Table H-1.54). In dry years, monthly average flows would decrease by a maximum of 2.2 cfs or 83% in July. In wet years, monthly average flows would decrease by a maximum of 1.0 cfs or 29% in May.

Below Denver Water's McQueary Creek Diversion, annual flows would decrease by 210 AF or 16% on average, 180 AF or 83% in dry years and 200 AF or 7% in wet years. At this location, monthly average flows would decrease by a maximum of 2.2 cfs or 29% in July (Table H-1.55). In dry years, monthly average flows would decrease by a maximum of 2.4 cfs or 81% in July. In wet years, monthly average flows would decrease by a maximum of 1.3 cfs or 29% in May.

Annual flows at the Williams Fork River below Steelman Creek gage, which is located below Denver Water's diversions from the Williams Fork Basin, would decrease by 1,300 AF or 14% on average, 1,300 AF or 59% in dry years and 1,200 AF or 6% in wet years. Monthly average flows would decrease by a maximum of 14.0 cfs or 28% in July (Table H-1.56). In dry years, monthly average flows would decrease by a maximum of 16.7 cfs or 80% in July. In wet years, monthly average flows would decrease by a maximum of 7.3 cfs or 27% in May.

Flows below Williams Fork Reservoir reflect differences in Gumlick Tunnel diversions and reservoir operations, including spills, substitution releases, exchange releases, and power releases to achieve operational goals, as well as other RFFAs. Differences in releases from Williams Fork Reservoir would generally follow the same pattern as the alternatives but would be higher. As shown in Tables H-7.1 through H-7.3, annual outflow from Williams Fork Reservoir would increase by 8,700 AF or 10% on average, 9,200 AF or 13% in dry years and 17,000 AF or 13% in wet years. Monthly average outflow would decrease by up to 6.4 cfs or 3% in August and increase by up to 66.9 cfs or 52% in July (Table H-1.57). In dry years, monthly average outflow would decrease by up to 1.0 cfs or 1% in April by up to 99.9 cfs or 150% in July. In wet years, monthly average outflow would decrease by up to 7.9 cfs or 2% in June and increase by up to 100.6 cfs or 27% in July.

Williams Fork River Native Stream Flows

Tables H-12.16 through H-12.19 show the native flow and the amount and percent diverted at Denver Water's diversions from the upper Williams Fork River tributaries under Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives. Similar to the action alternatives, additional native flow diversions would occur primarily in average and wet years during the runoff season from May through July. Under the No Action Alternative, the average annual percentage of native flow diverted would range from 57% at Denver Water's Jones Creek Diversion to 62% at their McQueary Creek Diversion. The average annual percentage of native flow diverted would increase by approximately 8% compared to Current Conditions (2006). There would be little increase in the percentage of native flow diverted in winter months. The increase in the percentage of native flow diverted from the upper Williams Fork River tributaries would be greatest in July. In July, the average annual percentage of native flow diverted by Denver Water from the upper Williams Fork River tributaries would increase by about 22% compared to Current Conditions (2006) with a maximum increase of 24% at Denver Water's Jones Creek Diversion.

Williams Fork River Daily Flow Changes

As shown by the flow duration curves (Figures H-5.12 through H-5.14), flow reductions resulting from the No Action Alternative would occur at higher flow rates, which typically correspond with wet years. The percentage of days that flow decreases would occur compared to Current Conditions (2006) is similar to the action alternatives, however, the percentage of time that there would be little to no change in flow (less than 1 cfs) would be higher under the No Action particularly at the locations above Williams Fork Reservoir. There would be little to no change in flow over 80% of the time at the upper basin locations and over 65% of the time below Williams Fork Reservoir. As shown in Table H-6.19, the maximum daily flow reductions at the upper basin locations would the same as the Proposed Action with RFFAs and slightly less than the Proposed Action with RFFAs below Williams Fork Reservoir.

Williams Fork River Floodplain

Changes in Williams Fork River flood flows and floodplain extents under No Action are similar to the Proposed Action with RFFAs in the upper basin. Below Williams Fork Reservoir, differences between Current Conditions (2006) and No Action are similar to differences between Current Conditions (2006) and the Proposed Action with RFFAs for recurrence intervals above 10 years. For recurrence intervals below that threshold, annual peaks due to spills are all higher under No Action than for Current Conditions (2006).

Colorado River

Colorado River Stream Flow

Changes in Colorado River flows below Windy Gap under the No Action Alternative would be due primarily to Denver Water's additional diversions from the Fraser and Williams Fork river basins and other RFFAs. Changes in stream flows described above for the Fraser and Williams Fork river basins would be translated downstream and into the Colorado River, but the reductions in flow would be smaller relative to the total stream, which is growing. Refer to Section 4.6.1.1.2 for a discussion of flow changes along the Colorado River related to other RFFAs since they would be similar to the Proposed Action with RFFAs.

As shown in Tables H-7.1 through H-7.3, annual flows below Windy Gap would decrease by 22,700 AF or 15% on average, increase by 30 AF or less than 1% in dry years and decrease by 45,900 AF or 11% in wet years. Annual flows below the confluence with Williams Fork River would decrease by 14,300 AF or 5% on average, increase by 8,900 AF or 6% in dry years and decrease by 29,100 AF or 5% in wet years. Annual flows at the gage near Kremmling would decrease by 60,300 AF or 9% on average, 4,900 AF or 1% in dry years and 84,100 AF or 7% in wet years.

Tables H-1.58, H-1.59, and H-1.60 summarize average monthly flow changes in the Colorado River below Windy Gap, below the confluence with Williams Fork River and near Kremmling for average, dry, and wet conditions, respectively. At these locations, flow reductions would occur in average and wet years and are highly concentrated during the runoff months in May, June, and July when the majority of additional diversions would occur. Below Windy Gap, monthly average flows would decrease by a maximum of 142.3 cfs or 32% in May (Table H-1.58). In dry years, monthly average flows would decrease by a maximum of 8.2 cfs or 6% in July. In wet years, monthly average flows would decrease by a maximum of 422.0 cfs or 31% in May.

Moving downstream, the Colorado River is affected by tributary inflows from the Williams Fork River, Troublesome Creek, Muddy Creek, and the Blue River, and changes in flows in those basins. Below the confluence with Williams Fork River, monthly average flows would decrease by a maximum of 128.2 cfs or 21% in June and increase by a maximum of 11.4 cfs or 4% in October (Table H-1.59). In dry years, monthly average flows would increase by a maximum of 90.3 cfs or 47% in July. In wet years, monthly average flows would decrease by a maximum of 422.2 cfs or 25% in May and increase by a maximum of 143.3 cfs or 8% in July. Near Kremmling, monthly average flows would decrease by a maximum of 398.6 cfs or 17% in June and increase by a maximum of 10.0 cfs or 2% in March (Table H-1.60). In dry years, monthly average flows would decrease by a maximum of 101.4 cfs or 9% in August and increase by a maximum of 10.1 cfs or 2% in April. In wet years, monthly average flows would decrease by a maximum of 500.2 cfs or 16% in May and increase by a maximum of 45.1 cfs or 5% in March.

Colorado River Daily Flow Changes

As shown by the flow duration curves (Figures H-5.15 through H-5.17), flow reductions resulting from the No Action Alternative would occur at higher flow rates, which typically correspond with wet years. The percentage of days that flow decreases would occur compared to Current Conditions (2006) is similar to the action alternatives (Table H-6.3). As shown in Table H-6.19, the maximum daily flow reductions below Windy Gap and the confluence with the Williams Fork River would be considerably less than the Proposed Action with RFFAs and slightly higher than the Proposed Action with RFFAs at the gage near Kremmling.

Colorado River Floodplain

Similar to the Proposed Action with RFFAs, annual flood flows for the Colorado River would be the same or lower under the No Action Alternative than under Current Conditions (2006) for most recurrence intervals. Several of the high recurrence interval peaks are the exceptions, due to the timing of Granby Reservoir spills. For recurrence intervals of approximately 8 years to 2.2 years, annual peaks are lower under No Action than under Current Conditions (2006), but not as low as for the Proposed Action with RFFAs. Below a recurrence interval of 2.2 years, annual peaks for No Action are the same as for Proposed Action with RFFAs. Accordingly, floodplain extent for a specified return interval under the Proposed Action with RFFAs would be the same or smaller as the corresponding floodplain under Current Conditions (2006), assuming that Granby Reservoir spills could be managed in real-time.

Muddy Creek

Muddy Creek Stream Flow

Changes along Muddy Creek and at Wolford Mountain Reservoir under the No Action Alternative would be primarily due to changes in Wolford Mountain Reservoir operations and other RFFAs as opposed to the Moffat Project. As shown in Tables H-7.1 through H-7.3, annual outflow from Wolford Mountain Reservoir would increase by 400 AF or 1% on average and 2,900 AF or 7% in dry years and decrease by 440 AF or less than 1% in wet years. Table H-1.61 summarizes average monthly outflow from Wolford Mountain Reservoir for average, dry, and wet conditions. Average monthly outflow would decrease up to 20.2 cfs or 6% in May and increase up to 12.1 cfs or 45% in January. In dry years, monthly average outflow would decrease up to 32.2 cfs or 23% in August and increase up to 19.4 cfs or 45% in July. In wet years, monthly average flows would decrease up to 66.0 cfs or 48% in April and increase up to 41.5 cfs or 131% in March.

Muddy Creek Daily Flow Changes

As shown by the flow duration curve (Figures H-5.18), flow reductions resulting from the No Action Alternative would occur at higher flow rates, which typically correspond with wet years. The percentage of days that flow decreases would occur compared to Current Conditions (2006) is the same as the action alternatives (Table H-6.4). As shown in Table H-6.19, the maximum daily flow reduction below Wolford Mountain Reservoir is the same as the Proposed Action with RFFAs.

Muddy Creek Floodplain

Changes in Muddy Creek flood flows and floodplain extents under the No Action Alternative are the same as for the Proposed Action with RFFAs.

Blue River

Changes in Blue River flows under the No Action Alternative would be due primarily to Denver Water's additional diversions through Roberts Tunnel. Roberts Tunnel diversions would increase substantially under the No Action Alternative compared to Current Conditions (2006), Full Use of the Existing System and the action alternatives because Denver Water would rely heavily on their Blue River supplies and Strategic Water Reserve to meet a higher demand, particularly during droughts. Unlike the action alternatives, monthly diversions would increase on average during the winter months because the Moffat WTP would be shut down during those months. Foothills and Marston WTPs would need to meet the entire demand though the winter, resulting in higher deliveries through Roberts Tunnel during those months.

Roberts Tunnel Diversions

As shown in Tables H-7.1 through H-7.3, annual Roberts Tunnel diversions would increase by 37,600 AF or 54% on average, which is approximately 5,000 AF to 6,000 AF higher than the action alternatives. Annual diversions would increase by 28,700 AF or 23% in dry years and 32,900 AF or 93% in wet years. Table H-1.62 summarizes average monthly diversions through the Roberts Tunnel for average, dry, and wet conditions. Diversions through Roberts Tunnel would increase on average in all months. Monthly average diversions would increase by a maximum of 135.5 cfs or 70% in September. In dry years, monthly average diversions would decrease up to 24.3 cfs or 8% in August and increase up to 81.3 cfs or 44% in October. In wet years, monthly average diversions would increase up to 143.3 cfs or 99% in September.

Blue River Stream Flow

Flows below Dillon Reservoir reflect differences in Roberts Tunnel diversions and spills. Annual outflow from Dillon Reservoir would decrease by 37,900 AF or 30% on average, 9,100 AF or 18% in dry years and 39,300 AF or 17% in wet years. Table H-1.63 summarizes average monthly outflow from Dillon Reservoir for average, dry, and wet conditions. In average and wet years, the greatest decrease in flows below Dillon Reservoir would generally be from May through August. Monthly average outflow would decrease up to 294.1 cfs or 38% in June. In dry years, monthly average outflow would decrease up to 72.5 cfs or 50% in July. In wet years, monthly average outflow would decrease up to 435.2 cfs or 46% in May.

Changes in average annual Blue River flows below Green Mountain Reservoir are roughly of the same magnitude as differences in outflow from Dillon Reservoir. Annual outflow from the reservoir would decrease by 38,300 AF or 13% on average, 9,700 AF or 5% in dry years and 46,000 AF or 10% in wet years. Table H-1.64 summarizes average monthly outflow from Green Mountain Reservoir for average, dry, and wet conditions. Monthly average outflow would decrease by a maximum of 316.3 cfs or 35% in June. In dry years, monthly average outflow would decrease by a maximum of 60.5 cfs or 11% in July. In wet years, monthly average outflow would decrease by a maximum of 338.4 cfs or 15% in June.

Blue River Daily Flow Changes

As shown by the flow duration curves (Figures H-5.19 and H-5.20), flow reductions resulting from the No Action Alternative would typically occur at higher flow rates. The percentage of days that flow decreases would occur is similar to the action alternatives (Table H-6.5). Flow decrease would occur more frequently because Denver Water would need to draw on their Blue River supplies more heavily under the No Action Alternative. As shown in Table H-6.19, the maximum daily flow reductions along the Blue River under the No Action Alternative would be the same as the action alternatives.

Blue River Floodplain

Under the No Action Alternative, annual peak flows below Dillon Reservoir would be consistently less than annual peak flows under Current Conditions (2006), for a given recurrence interval. Accordingly, floodplain extents from Dillon Reservoir to Green Mountain Reservoir would be the same or smaller under the No Action Alternative compared with Current Conditions (2006). Below Green Mountain Reservoir, annual peaks are similar to the Proposed Action with RFFAs, which means minor effects to floodplain size are possible. However, daily flow data shows that peaks could potentially be attenuated by releasing more water from Green Mountain Reservoir pre-emptively.

South Boulder Creek

South Boulder Creek Stream Flow

In the uppermost reach above Gross Reservoir, changes in flow are equivalent to changes in Moffat Tunnel deliveries. As shown in Tables H-7.1 through H-7.3, annual flows at the Pinecliffe gage would increase by 5,000 AF or 5% on average, 1,500 or 2% in dry years and 8,400 AF or 8% in wet years. The combination of 5 years that were averaged to determine a wet and dry year average are different for the Moffat Tunnel versus South Boulder Creek because diversions into the Moffat Tunnel occur on the West Slope, whereas South Boulder Creek is located on the East Slope. Refer to Section 4.6.1 for a discussion of West Slope versus East Slope dry and wet year averages. As a result, the changes in wet and dry year annual averages are not comparable for the Moffat Tunnel and Pinecliffe gage.

Table H-1.65 summarizes average monthly flows at the Pinecliffe gage for average, dry, and wet conditions. Flow increases would occur primarily in May, June, and July, which corresponds with the months when additional diversions through Moffat Tunnel would be greatest. There would be virtually no flow increases from late summer through early spring except in infrequent, very wet years. There would be flow decreases in South Boulder Creek in winter months due to reduced Moffat Tunnel diversions during those months compared to Current Conditions (2006). Some of the water that would be diverted through the Moffat Tunnel under Current Conditions (2006) would be diverted for snowmaking purposes in the Fraser River Basin instead because those demands increase under the No Action Alternative. Monthly average flows would increase up to 36.6 cfs or 6% in June. In dry years, monthly dry year average flows would increase up to 16.0 cfs or 11% in July. As discussed under the section for the Fraser River, Moffat Tunnel diversions would increase in dry years due to reductions in bypass flows in the Fraser River Basin as Denver Water's demands increase from Current Conditions (2006) to Full Use of the Existing System. As a result, flow increases would occur in South Boulder Creek above Gross Reservoir in dry years. In wet years, monthly wet year average flows would increase up to 63.1 cfs or 14% in June.

From Gross Reservoir to the South Boulder Diversion Canal, changes in flow reflect Gross Reservoir operations. Unlike the action alternatives, the Moffat WTP would be shut down from mid-October to April or May depending on the year and the South Boulder Diversion Canal would be shut down from mid-December through mid-March. As a result, Gross Reservoir outflow would not change in January and February. During those months, Foothills and Marston WTPs would need to meet the entire demand. However, flows would be consistently higher from March through December as more water is released to meet additional demand. As shown in Tables H-7.1 through H-7.3, average, dry year and wet year annual outflow from Gross Reservoir would increase by 4,900 AF or 4%, 4,900 AF or 6%, and 7,500 AF or 7%, respectively. Increases in average annual releases are approximately 7,000 AF less compared with the action alternatives. Table H-1.66 summarizes average monthly outflow from Gross Reservoir for average, dry, and wet conditions. Monthly average outflow would increase up to 44.6 cfs or 53% in March and decrease up to 37.8 or 23% in September. In dry years, monthly average outflow would increase up to 48.6 cfs or 59% in March and decrease up to 15.8 cfs or 9% in August. In wet years, monthly average outflow would increase up to 48.7 cfs or 13% in July and decrease up to 20.7 cfs or 11% in September.

Below the South Boulder Diversion Canal, flows would generally decrease on average under the No Action Alternative because Denver Water would divert slightly more native South Boulder Creek water, either to storage at Gross Reservoir or under their direct diversion right at the South Boulder Diversion Canal. As shown in Tables H-7.1 through H-7.3, annual flows at the Eldorado Springs gage would decrease by 590 AF or 1% on average, 2,500 AF or 4% in wet years, and changes in flow in dry years would be minimal. Table H-1.67 summarizes average monthly flow at the South Boulder Creek near Eldorado Springs gage. Monthly average flows would decrease up to 6.2 cfs or 2% in June. In wet years, monthly average flows would decrease up to 22.7 cfs or 7% in June.

South Boulder Creek Native Stream Flow

Table H-12.20 shows the native flow at the South Boulder Creek at Pinecliffe gage and the amount and percentage added due to additional Moffat Tunnel delivery under Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives. Under the No Action Alternative, the average annual Moffat Tunnel delivery to South Boulder Creek increases from 151% under Current Conditions (2006) to 162% of the native flow under No Action. The increase in flow added to this river segment is greatest during the runoff season from May through July in average and wet years. In average years, the Moffat Tunnel delivery ranges up to 426% of the native flow in September. Average monthly native flows and Moffat Tunnel deliveries are 18.0 cfs and 76.8 cfs, respectively in September. In wet years, the Moffat Tunnel delivery ranges up to 669% of the native flow in September. Average monthly native flows and Moffat Tunnel deliveries are 15.9 cfs and 106.0 cfs, respectively in September in a wet year. While, the percentage of flow added to South Boulder Creek from the Moffat Tunnel is significant, the section of South Boulder Creek above Gross Reservoir has been modified to accommodate up to 1,200 cfs at the Pinecliffe gage.

South Boulder Creek Daily Flow Changes

As shown by the flow duration curves (Figures H-5.21 through H-5.23), flow increases above Gross Reservoir resulting from the No Action Alternative would occur primarily at higher flow rates. The flow duration curve for the No Action Alternative is very similar to the curve for Full Use of the Existing System. The flow duration curve for Gross Reservoir outflow shows flow increases throughout range of flows that would occur would be relatively small. The flow duration curve at the Eldorado Springs gage shows flow decreases would be minor and occur primarily at higher flow rates.

The percentage of days that flow changes would occur compared to Current Conditions (2006) is shown in Table H-6.6. At the Pinecliffe gage, the flow change from May through July would be less than 1 cfs about 28% of the time. Flows would increase up to 100 cfs about 60% of the time. Below Gross Reservoir, the flow change would be less than 1 cfs about 28% of the time. Flow flows would decrease or increase up to 100 cfs about 21% and 46% of the time, respectively. At the Eldorado Springs gage, the percentage of days flows would change would be similar to the Proposed Action with RFFAs. As shown in Table H-6.19, the maximum flow reduction at the Pinecliffe gage would be 525 cfs under No Action, which is over double the maximum flow reduction under the Proposed Action with RFFAs. Below Gross Reservoir and at the Eldorado Springs gage, the maximum flow reduction under the No Action Alternative would be similar to the Proposed Action with RFFAs.

South Boulder Creek Floodplain

Upstream of Gross Reservoir, annual flood events for the No Action Alternative are virtually the same as for Current Conditions (2006) for recurrence intervals of 2.4 years or more. Below this threshold, flood events would increase slightly but peak flows would be well within the capacity of the channel. Below Gross Reservoir, annual floods are consistently higher under the No Action Alternative than under Current Conditions (2006) by up to 5%. This could result in minor differences in the floodplain below Gross Reservoir.

North Fork South Platte River

North Fork South Platte River Stream Flow

The changes in flow in the North Fork South Platte River are equivalent to changes in Roberts Tunnel deliveries. Unlike the action alternatives, monthly flows would increase on average during the winter months because the Moffat WTP would be shut down during those months. Foothills and Marston WTPs would need to meet the entire demand through the winter, resulting in higher deliveries through Roberts Tunnel during those months. Flow changes at the Geneva Creek gage are slightly less than changes in diversions at the Roberts Tunnel due to transit losses because the State Engineer’s Office assesses a 5% transit loss on Denver Water’s Roberts Tunnel deliveries to the North Fork South Platte River. Moving downstream, the volume of change along the North Fork South Platte River stays the same, however, the percentage change in flow is smaller relative to the total stream, which is growing.

As shown in Tables H-7.1 through H-7.3, annual flows at the Geneva Creek gage would increase by 36,200 AF or 31% on average, 38,800 AF or 26% in dry years, and 27,200 AF or 28% in wet years, respectively. Note, that the combination of 5 years that were averaged to determine a wet and dry year average are different for the Roberts Tunnel versus the North Fork South Platte River because diversions at the Roberts Tunnel occur on the West Slope, whereas the North Fork South Platte River is located on the East Slope. Refer to Section 4.6.1 for a discussion of West Slope versus East Slope dry and wet year averages. Table H-1.68 summarizes average monthly flows in the North Fork South Platte River below Geneva Creek gage for average, dry, and wet conditions. Monthly average flows would increase up to 130.9 cfs or 56% in September. In dry years, monthly average flows would increase up to 116.0 cfs or 34% in June. In wet years, monthly average flows would increase up to 120.9 cfs or 76% in September.

North Fork South Platte River Native Stream Flow

Table H-12.21 shows the native flow and the amount and percentage added to the North Fork South Platte River below Geneva Creek gage due to Denver Water's additional Roberts Tunnel deliveries under Current Conditions (2006), Full Use of the Existing System, No Action and each of the action alternatives. Under the No Action Alternative, the average annual Roberts Tunnel delivery to the North Fork South Platte River increases from 131% under Current Conditions (2006) to 202% of the native flow under No Action. The increase in flow added to this river segment is greatest in dry years in the summer and fall. In average years, the Roberts Tunnel delivery ranges up to 640% of the native flow in September. Average monthly native flows and Roberts Tunnel deliveries are 49.5 cfs and 316.6 cfs, respectively in September. In dry years, the Roberts Tunnel delivery ranges up to 844% of the native flow in October. Average monthly native flows and Roberts Tunnel deliveries are 31.7 cfs and 267.2 cfs, respectively in October in a dry year. While, the percentage of flow added to the North Fork South Platte River from the Roberts Tunnel is significant, the river segment below the Roberts Tunnel outfall has been modified to accommodate up 680 cfs (daily average) at Grant and 980 cfs (daily average) above the confluence with the mainstem.

North Fork South Platte River Daily Flow Changes

As shown by the flow duration curve for the North Fork South Platte River below Geneva Creek gage (Figure H-5.24), flows consistently increase at all levels and particularly at higher flow rates, which generally correspond with summer months. About 81% of the time there would be little to no flow change, or a flow increase or decrease up to 100 cfs would occur (Table H-6.7). The maximum daily flow reduction at the Geneva Creek gage would be 553 cfs, which is similar the Proposed Action with RFFAs. The maximum daily flow increases would be similar to the action alternatives.

North Fork South Platte River Floodplain

Changes in flood flows and floodplain extents under the No Action Alternative would be similar to the Proposed Action with RFFAs.

South Platte River

South Platte River Stream Flow

For the purpose of analyzing changes in surface water hydrology along the South Platte River under the Proposed Action with RFFAs, modeled diversions and stream flows were analyzed below Antero, Eleven Mile Canyon, Cheesman, and Chatfield reservoirs, and at the South Platte River at three USGS gages - Waterton, Denver, and Henderson.

Antero Reservoir to Cheesman Reservoir. In the upper South Platte River, above the confluence with the North Fork South Platte River, changes in South Platte River flows under the No Action Alternative would be due primarily to Denver Water's additional diversions and reservoir releases. Reservoir releases would increase substantially under the No Action Alternative in dry years compared to Current Conditions (2006), Full Use of the Existing System and the action alternatives because Denver Water would rely more heavily on their South Platte River supplies and Strategic Water Reserve to meet a higher demand during droughts. In addition, the Moffat WTP is shut down during the winter months unlike the action alternatives; therefore, Foothills and Marston WTPs would need to meet Denver Water's entire demand though the winter, resulting in higher reservoir releases during the winter months.

As shown in Tables H-7.1 through H-7.3, annual outflow from Antero Reservoir changes less than 300 AF on average. There would be relatively little change in Antero Reservoir releases under the No Action Alternative because of the infrequency that Denver Water uses Antero Reservoir. Releases are typically only made in the later stages of a drought. Annual outflow from Eleven Mile Canyon and Cheesman reservoirs increases by less than 1,500 AF or 1% on average and in wet years. In dry years, annual outflow at Eleven Mile Canyon and Cheesman reservoirs increases by 3,100 AF or 3%, and 16,800 AF or 12%, respectively. Average annual releases from Cheesman Reservoir are approximately 7,500 AF more in dry years than under the action alternatives. Tables H-1.69 through H-1.71 summarize average monthly outflow from Antero, Eleven Mile Canyon, and Cheesman reservoirs for average, dry, and wet conditions. Changes in monthly average outflow below Antero Reservoir would be relatively small and range up to about 4 cfs (Table H-1.69). Changes in monthly average outflow below Eleven Mile Canyon Reservoir would also be relatively small on average and in wet years (plus or minus about 10 cfs), however, changes in monthly average outflow in dry years would range from a maximum decrease of 7.4 cfs or 5% in May to a maximum increase of 34.5 cfs or 19% in August (Table H-1.70). Monthly average outflow from Cheesman Reservoir would decrease up to 24.5 cfs or 5% in June and increase up to 16.2 cfs or 13% in November (Table H-1.71). In dry years, monthly average outflow would decrease up to 10.0 cfs or 6% in October and increase up to 66.9 cfs or 26% in September. In wet years, monthly average outflow would decrease up to 21.3 cfs or 10% in October and increase up to 19.3 cfs or 2% in May.

Cheesman Reservoir to South Platte River at Waterton Gage. Denver Water's direct diversions and exchanges to Strontia Springs Reservoir and Conduit 20 would change under the No Action Alternative primarily in response to a higher demand. As a result, South Platte River flows at the Waterton gage would decrease primarily during summer months. There would be little change in flows at Waterton gage in most winter months from

October through March; however, flow decreases would occasionally occur from October through December and March.

In the summer, Foothills and Marston WTPs would operate at higher rates under the No Action Alternative because of the overall higher level of demand. Therefore, Denver Water's direct diversions at Strontia Springs Reservoir and Conduit 20 would increase in response to higher demand in summer months. The greatest increases in direct diversions would typically occur in the months of May through August. In addition, exchanges to Conduit 20 would also increase in summer months for similar reasons. Because summer diversions through Roberts Tunnel would generally be higher under the No Action Alternative, more reusable effluent at the Metro WWTP and Bi-City WWTP would be available for exchange. The increase in available reusable effluent combined with the increased operation of Foothills and Marston WTPs in the summer, would result in increased exchanges to Conduit 20 on average. The majority of additional exchanges would occur from April through September.

As shown in Tables H-7.1 through H-7.3, annual flows at the Waterton gage would decrease by 15,300 AF or 14% on average, 2,000 AF or 6% in dry years, and 20,900 AF or 7% in wet years respectively. Table H-1.72 summarizes average monthly flows at the South Platte River at Waterton gage for average, dry, and wet conditions. Monthly average flows would decrease up to 67.5 cfs or 30% in August. In dry years, monthly average flows would decrease up to 15.0 cfs or 33% in April. In wet years, monthly average flows would decrease up to 71.7 cfs or 15% in April.

<u>South Platte River at Waterton Gage to South Platte River at Denver Gage</u>. Monthly outflow Chatfield Reservoir would decrease on average from October through March by up to 6.4 cfs. Average monthly outflow in the remaining months would decrease up to 76.4 cfs in August. Flow reductions during the summer are considerably higher because that is when the majority of additional direct diversions and exchanges would occur. As shown in Tables H-7.1 through H-7.3, annual outflow from Chatfield Reservoir would decrease by 17,100 AF or 14% on average, 3,700 AF or 17% in dry years, and 22,000 AF or 6% in wet years, respectively. Table H-1.73 summarizes average monthly outflow from Chatfield Reservoir for average, dry, and wet conditions. Monthly average outflow would decrease by a maximum of 76.4 cfs or 35% in August. In dry years, monthly average outflow would decrease up to 20.7 cfs or 50% in August and increase up to 5.9 cfs or 34% in November. In wet years, monthly average flows would decrease up to 77.1 cfs or 4% in June and increase up to 8.1 cfs or 12% in March.

Monthly flows at the Denver gage would decrease on average from April through September and increase from October through March. Flows would decrease during the summer due to increased demand and additional direct diversions and exchanges up to Strontia Springs Reservoir and Conduit 20. The majority of the additional direct diversions and exchanges would occur from April through September. Flows would increase during the winter due to additional returns from indoor and outdoor water usage. There would also be differences associated with changes in the amount and timing of water moved between Strontia Springs, Chatfield, and Marston reservoirs.

As shown in Tables H-7.1 through H-7.3, annual flows at the Denver gage would decrease by 10,300 AF or 4% on average, increase by 4,900 AF or 5% in dry years, and decrease by

14,600 AF or 3% in wet years, respectively. Table H-1.74 summarizes average monthly flows at South Platte River at Denver gage for average, dry, and wet conditions. Monthly average flows would decrease up to 64.5 cfs or 16% in August and increase up to 9.3 cfs or 7% in November. In dry years, monthly average flows would decrease up to 9.8 cfs or 6% in August and increase up to 27.0 cfs or 30% in November. In wet years, monthly average flows would decrease up to 67.6 cfs or 3% in June and increase up to 14.4 cfs or 6% in March.

<u>South Platte River at Denver Gage to South Platte River at Henderson Gage</u>. In the reach along the South Platte River between the Denver gage and Henderson gage, flows would decrease on average compared to Current Conditions (2006), however, the reduction in flow is less at the Henderson gage than at the Denver gage. The reduction in flow decreases due to additional effluent returns at the Metro WWTP and return flows accruing to the river due to Denver Water's additional outdoor water usage.

Flows at the Henderson gage would generally increase on average during the fall and winter months because there are additional indoor and outdoor return flows attributable to Denver Water's increased demands and additional direct diversions and exchanges up to Strontia Springs and Conduit 20 are fairly minimal. The changes in flows from May through September would be more variable with monthly flow increases ranging up to about 6,400 AF and decreases ranging up to about 33,500 AF.

As shown in Tables H-7.1 through H-7.3, annual flows at the Henderson gage would decrease by 4,700 AF or 2% on average, increase by 6,000 AF or 5% in dry years, and decrease by 9,800 AF or 1% in wet years, respectively. Table H-1.75 summarizes average monthly flows at the Henderson gage for average, dry, and wet dry conditions. Monthly average flows would decrease up to 53.7 cfs or 18% in April and increase up to 14.6 cfs or 2% in July. In dry years, monthly average flows would decrease up to 1.9 cfs or 3% in December and increase up to 24.5 cfs or 12% in August. In wet years, monthly average flows would decrease up to 177.9 cfs or 19% in April and increase up to 43.4 cfs or 3% in July.

South Platte River Daily Flow Changes

As shown by the flow duration curves for the South Platte River, flow changes are relatively small the majority of time (Figures H-5.25 through H-5.30). As shown in Table H-6.8, flow changes of 100 cfs or less would occur at least 89% of the time at all locations of interest along the South Platte River. Maximum daily flow reductions are generally higher than the action alternatives, as shown in Table H-6.19. The maximum daily flow reduction would range from 660 cfs below Antero Reservoir to 1809 at the Denver gage. The maximum daily flow increase would range from 474 cfs below Eleven Mile Canyon Reservoir to 700 cfs below Antero Reservoir. The difference in maximum daily flow increases and reductions in comparison to the action alternatives is a function of reservoir releases extending a few days longer or shutting off a few days earlier.

South Platte River South Platte River Floodplain

Changes in flood flows and floodplain extents along the South Platte River below Cheesman Reservoir would be the same as for the Proposed Action with RFFAs.

At the Denver gage, there would be no increase in annual peaks under the No Action Alternative, compared with Current Conditions (2006) for recurrence intervals greater than 2.2 years. For events with recurrence intervals less 2.2 years, flood flows are generally smaller for the No Action Alternative compared to Current Conditions (2006).

4.6.1.6.4 Combination Strategy

A qualitative assessment of the combination of using mandatory restrictions in addition to depleting the Strategic Water Reserve was conducted for the No Action Alternative. The following compares the hydrologic affects of the Combination Strategy with relying solely on the Strategic Water Reserve.

In dry years, Denver Water would divert the maximum amount physically and legally available under their existing water rights. Imposing restrictions would allow Denver Water to decrease bypass flows on the West Slope, which would increase the amount physically available for Denver Water to divert. If Denver Water diverts additional water due to decreased bypass flows, flows would decrease on the West Slope. In addition, flows could decrease in dry years if greater restrictions were imposed because less water would be released from storage.

Imposing restrictions would generally have the impact of preserving more of the Strategic Water Reserve; therefore, storage contents in Denver Water’s reservoirs would likely be higher during a drought as compared to not imposing restrictions. Whether storage contents are higher depends on several factors. The amount and location of water reserved in storage would vary depending on the severity and duration of restrictions imposed, on storage conditions in Denver Water’s North and South systems and on hydrologic conditions. Since storage contents could be higher with restrictions after a drought, Denver Water’s diversions into storage could be less and stream flows could increase for a short duration after Denver Water’s reservoirs refill. However, this would not occur if a reservoir is drained even with restrictions in place. Conversely, with greater restrictions, during a drought stream flows would be less in some streams as Denver Water would decrease its releases from storage and decrease bypass flows. In summary, if mandatory restrictions were imposed in combination with depleting the Strategic Water Reserve, the following hydrologic impacts are likely to occur:

- Steam flows would also decrease if bypass flows are decreased. For example, Denver Water would divert additional water from the Fraser River in dry years if bypass flows are reduced. This applies to several locations in the Fraser River Basin, the Blue River below Dillon Reservoir, and along the South Platte River below Eleven Mile Canyon Reservoir and Cheesman Reservoir, and at the Old Last Chance Ditch Diversion.
- Stream flows would increase along South Boulder Creek above Gross Reservoir if bypass flows in the Fraser River Basin are decreased since more water would be diverted through Moffat Tunnel.
- Stream flows could increase below Williams Fork Reservoir if additional releases are required to replace out-of-priority diversions at Dillon Reservoir or through Moffat Tunnel if bypass flows are reduced.

- Following a drought, stream flows could be higher for a short duration if Denver Water refills its reservoirs sooner. However, this would not occur if a reservoir is drained even with restrictions in place.
- Reservoir contents would be higher during a drought; however, the combination strategy does not guarantee the reservoirs would not be drained.

4.6.2 Water Quality

The affected water quality environment is described for Current Conditions (2006) in Section 3.2. This cumulative impacts analysis evaluates the changes in water quality due to flow changes and reservoir operations associated with each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs) and past actions such as stream diversions and water supply projects. The total effects analysis also addresses stream segments downstream of the Project area that are listed on the State of Colorado’s Section 303(d) or Monitoring and Evaluation List (CDPHE 2012a), as well as segments with established total maximum daily loads (TMDLs) (CDPHE 2012b).

As described in Section 3.2, the Project area is comprised of rivers and streams supporting diverse watersheds and ecosystems ranging from pristine unregulated alpine watersheds at the Continental Divide to heavily regulated systems at the lower-elevation areas where the Colorado and South Platte rivers exit the Project area. Water management in these diverse watersheds is affected by a wide range of human activities, including diversions (for municipal, domestic, industrial, and recreational uses) and different types of return flows (agricultural runoff, wastewater plant discharges, and storm water). The Project alternatives considered in this Environmental Impact Statement (EIS) would alter stream flows in the most ecologically sensitive sub-basins in average to wet years, not in dry years and in low-flow periods of wetter years due to lack of water availability at existing diversions during those times and due to existing legal constraints on additional diversions during those times (bypass agreements). Therefore, the assessment of potential effects on stream water quality was focused on the flow conditions that would exist at the times the Project alternatives would be altering flows. The assessment methods were selected for applicability to these conditions and for assessing effects on ecological resources and on existing and potential future human uses and activities. In cases where Platte and Colorado Simulation Model (PACSM) results indicate a change in flow greater than 10 percent (%), discussion and/or evaluation is provided under each alternative.

Predicted effects on water temperature, nutrient levels, and wastewater permits are evaluated for streams and reservoirs in the Project area. This section also includes a detailed review of water quality issues within the Fraser River and its tributaries in recognition of: (a) Current Conditions reflecting relatively extensive water withdrawals and competing water uses; (b) potential ecological impacts in the vicinity of proposed stream diversions; (c) potential effects on ability of the owners of existing Wastewater Treatment Plants (WWTPs) to maintain compliance with their discharge permit conditions; and (d) magnitude of agency and public comment on the Draft EIS.

Methods for Reservoir Water Quality Evaluation

Methods used to assess in-reservoir water quality for the reservoirs in the Project area are summarized below. In some cases, water quality data collected subsequent to 2006 were used to support analyses. This was done for several analyses conducted or revised in response to agency comments. Recent data were considered in cases where it was found to provide critical additional information. Specifically, data subsequent to 2006 were considered in development of the Fraser River Nutrient Model calibration targets, assumptions for WWTP nutrient concentrations, the Shadow Mountain Reservoir dissolved oxygen (DO) regression analysis, the Gross Reservoir temperature model, and assessment of stream temperature changes below Gross Reservoir. Detailed descriptions of the methods can be found in Section 4.6.2.1.

Gross Reservoir

Under the Proposed Action, the depth and capacity of Gross Reservoir would increase substantially. For assessment of potential changes to in-reservoir water quality, results from the Gross Reservoir Temperature Model (Hawley et al. 2013 in Appendix E-5) were considered along with empirical relationships from Vollenweider (1976). The analysis is described in detail in Section 4.6.2.1.1. Current Conditions (2006) and the Proposed Action with RFFAs were evaluated and compared.

Grand Lake, Shadow Mountain Reservoir, and Granby Reservoir (The Three Lakes)

The Three Lakes have recently received considerable attention over possible water quality changes resulting from any activity. To evaluate potential impacts on this system, an existing water quality model was used. The Three Lakes Water-Quality Model (AMEC 2008) was developed over a period of several years with involvement and review of many stakeholders. This process-based model simulates nutrients, chlorophyll *a*, DO, water clarity, and total suspended solids on a daily basis for each of the three water bodies. The model is described further in Section 4.6.2.1.1. Current Conditions (2006) and each of the Project alternatives with RFFAs were evaluated and compared.

All Other Reservoirs

Other reservoirs in the Project area include:

- Williams Fork Reservoir;
- Dillon Reservoir;
- Wolford Mountain Reservoir;
- Antero Reservoir;
- Eleven Mile Canyon Reservoir;
- Cheesman Reservoir;
- Strontia Springs; and
- Chatfield Reservoir.

Potential effects on the water quality of these reservoirs were assessed on a qualitative basis consistent with the relatively limited changes that the Project alternatives with RFFAs would have on the inflow, outflow, reservoir level, and residence times for these reservoirs.

Methods for Stream Water Quality Evaluation

This subsection describes methods used to assess potential effects on stream water quality throughout the very diverse Project area.

For each basin in the Project area, potential water quality changes resulting from the Moffat Project alternatives with RFFAs were evaluated based on one or more of the following categories depending on the ecological conditions and concerns in the basins and on existing and potential diversions and return flows:

- **Impaired Water Bodies** – Potential to cause exceedances or contribute to potential exceedances for (1) Regulation 93 constituents (the Monitoring and Evaluation List, Impaired Water Body List [Section 303(d) List]), or (2) TMDLs
- **Effects on Wastewater Treatment Plant Operations and Discharges** – Potential to affect the operations of existing WWTPs and for wastewater discharges to adversely affect stream water quality due to reductions in dilutive flows
- **Effects on Source Waters for Potable Water Systems** – Potential to affect the quality of source waters used by potable water systems or other potential site-specific effects
- **Effects on Water Bodies** – Potential to affect the quality of the water entering an existing water body (such as changes in the quality of water imported from separate river basin affecting the quality of water in the receiving water bodies)

The methods used to assess these four categories of effects are presented in four subsections below. The following primary information sources were used to support these four types of effects assessments:

- Water quality data as presented in Section 3.2 for sampling sites that are near or exceed existing water quality standards listed in Colorado Department of Public Health and Environment (CDPHE) Regulations
- PACSM hydrologic modeling results as presented in Appendix H and Section 4.6.1
- Completed and draft TMDLs as published on CDPHE's website (CDPHE 2012b)
- Colorado's Section 303(d) and Monitoring and Evaluation Lists as presented in CDPHE Regulation 93 (CDPHE 2012a)
- National Pollutant Discharge Elimination System (NPDES) permitted discharges as listed in the U.S. Environmental Protection Agency's (EPA's) Enforcement and Compliance History Online and Envirofacts databases (construction-related permits are not evaluated, as these are temporary) (EPA 2007b, 2010a)
- Potable drinking water system information as published in EPA's Envirofacts database (EPA 2007c)

Impaired Water Bodies

Regulation 93 (CDPHE 2012a) lists impaired stream segments that identify parameter(s) of interest for each segment. (See Section 3.2.0 of this EIS for explanations of the State of Colorado Section 303(d) List and Regulation 93.) For these stream segments, CDPHE does not identify sources of pollution nor do they specify potential methods for reducing parameter concentrations or loadings. For stream segments with TMDLs, the source of pollution is identified, as well as methods to reduce or remove concentrations of the pollutants. The source or potential source of identified pollutants is reviewed in terms of 2032 conditions where a potential change in pollutant concentration would occur as a result of the Project alternatives with RFFAs.

Regulation 93 identifies temperature as a concern in a number of stream segments in the upper Colorado River Basin. While water temperature in streams is influenced by many factors, solar radiation directly affects heat exchanged between the water and the atmosphere. Tributary temperatures, groundwater inflow and precipitation are also factors. A number of studies have indicated that air temperature/solar radiation have the greatest impact on stream water temperature. Additional factors include riparian vegetation (shading and insulation), topographic shading, relative humidity, wind velocity, streambed conductivity, and channel morphology (Katzenberger and Mason n.d.; Poole and Berman 2001; Bartholow 1989; Essig 1998; Amaranthus et al. 1989). Input data required by temperature models, such as SSTEMP, include meteorological data (air temperature, humidity, wind speed, and cloud cover), a shade factor, and physical parameters such as flow and streambed dimensions (USGS 2010b). In sensitivity analyses using the Instream Water Temperature Model (SNTEMP), Bartholow determined that stream flow was the fourth most important variable affecting stream water temperature, after air temperature, percent shade, and relative humidity (Bartholow 1989). Reductions in flow rates in a reach of stream affect stream temperatures primarily by increasing the surface area of a stream in relation to the volume of water in the reach. Riparian vegetation affects heat exchange through shading, reduces wind velocity at the water surface, and provides an insulating effect of air temperature at the water surface. Other influences on stream water temperature include reduction of shade (for example, through disturbance of riparian vegetation from livestock grazing or back erosion due to rapidly varying flow rates), increases in width-to-depth ratio due to increased sedimentation or reduced flows, reduced flow due to upstream diversions or storage and changes in vegetation, land use, or other conditions that alter groundwater flows.

A review of approved TMDLs for water temperature in mountainous streams (NMED 1999, 2002; UDEQ 2010) showed that loss of riparian vegetation, an increase in sedimentation, and reduction of late summer flows were identified as contributors to changes in water temperatures. In New Mexico, Best Management Practices (BMPs) to increase riparian shade and reduce sedimentation concluded that increasing riparian shade by 55 to 60% could result in meeting the stream standards in that setting.

Although many factors affect stream temperatures, focused investigations were conducted in response to discussions with Cooperating Agencies (described in Chapter 6) to determine whether single-variable regression analyses could be used to develop relationships to predict changes in stream temperatures caused solely by: (1) changes in stream flows, and (2) changes in air temperature. The following analyses were performed:

- Examination of potential relationship between air temperature and water temperature at a number of stations
- Examination of potential relationship between flow and water temperature at a number of stations

- Examination of historical data for water temperatures near or above the stream standard and associated flow at that time

These analyses are expected to be supplemented by dynamic stream temperature modeling performed in support of the Clean Water Act Section 401 water quality certification process administered by CDPHE separate from this EIS.

There are no predicted changes in geomorphology that are expected to directly affect stream temperature. Changes in channel morphology could result from development and other land use practices as well as additional sediment loading in streams. In these cases, increased sediment loads would be the result of activities such as urbanization, bank instability, loss of riparian vegetation (and corresponding stream shading), and/or grazing practices. It is not anticipated that the Proposed Action or RFFAs would extend or increase these practices and conditions. Furthermore, the sediment supply, which is related to flow rates, would decrease rather than increase as a result of the Proposed Action with RFFAs. Therefore, geomorphology as it relates to stream temperature is not discussed further.

An evaluation of the available water quality data was conducted in attempt to characterize the seasonal fluctuations in existing water quality within the Project area to support evaluations of how these fluctuations would relate to the operation patterns of the Moffat Project alternatives. Based on this evaluation, it was concluded that sufficient water quality data do not exist to appropriately characterize the seasonal fluctuations in existing water quality within the Project area. The absence of representative seasonal water quality data is, in large part, attributable to the fact that water quality sampling tends to occur in focused efforts during specific periods of interest (e.g., low flow periods) rather than on a consistent temporally distributed basis. Therefore, it was determined that this type of analysis would not be feasible as part of this EIS.

Effects on Wastewater Treatment Plant Operations and Discharges

The Proposed Action with RFFAs could adversely affect the ability of wastewater plant operators to maintain compliance with current and future discharge regulations due to potential flow reductions and reduced dilutive capacity in the receiving streams. Furthermore, changes in stream flow could drive changes in permit conditions. Evaluation of potential impacts to wastewater dischargers was based on potential changes in low flows at the discharge point. Evaluation of water quality for altered stream flows was evaluated in two ways. For the Fraser River, nutrient concentrations have been modeled under various conditions and are described in more detail later in this section. For the Fraser River and the remaining basins, the percentages of stream flows that would be comprised of treated effluent were estimated in accordance with CDPHE procedures and the impacts are discussed. For other basins, where potential for increased nutrient loading would not be significant, the loads were not evaluated explicitly, but the percent of the stream comprised of wastewater effluent was evaluated.

The impact of potential future regulations, including nutrient regulation, was not quantified as the final content of those regulations had not been released at the time of evaluation. Regulatory changes currently being discussed would regulate nitrogen and phosphorus as numeric criteria rather than the current narrative criteria. The proposed regulation changes for nitrogen and phosphorus would likely result in more stringent discharge criteria for many WWTPs.

Effects on Source Waters for Potable Water Systems

Potable water providers could be impacted if changes in contaminant concentrations in regulated drinking water parameters result from potential water transfers. These impacts are discussed for potable water providers that use water sources from affected stream segments in water basins within the Project area. For all alternatives, historical operational patterns of water transfers through the Moffat and Roberts tunnels would be similar but the quantity of water transferred would change. There is also potential for transfer of organisms, including those pathogenic to humans, from importing surface waters. For Alternatives 8a, 10a, and 13a, additional transfer of water would occur from the South Platte River Basin, downstream of the Metro Wastewater Reclamation District Plant (Metro WWTP). To ensure potable water quality standards, these three alternatives were configured to include the Advanced Water Treatment Plant (AWTP) to remove potential pathogenic organisms and chemical and physical contaminants.

Effects on Water Bodies

The quality of water bodies can be altered through changes in the quality of inflows to the water body (or "source" waters). These potential effects were evaluated based on the potential causes of change in source water quality. For increases or decreases in flows from an imported source (for example, a trans-basin diversion tunnel), guidance was used from the Antidegradation Significance Determination for New or Increased Water Quality Impacts Procedural Guidance (CDPHE 2001). Per the guidance document, "In order to be 'insignificant,' the new or increased discharge may not increase the actual instream concentration by more than 15% of the available increment over the baseline." For purposes of this EIS, baseline is defined as ambient stream conditions as presented in Section 3.2. Ambient stream quality was determined using CDPHE guidance for data quality, specifically where data points covered multiple years with multiple samples per year. The procedures and criteria used include:

- **Guidance on Data Requirements and Data Interpretation Methods Used in Stream Standards and Classification Proceedings**. Water Quality Control Division, July 1993 (CDPHE 1993)
- **Regulation No. 31. The Basic Standards and Methodologies for Surface Water**. Effective January 1, 2011 (CDPHE 2011a)
- **Antidegradation Significance Determination for New or Increased Water Quality Impacts. Procedural Guidance**. Version 1.0. December 2001 (CDPHE 2001)
- **Guidance on Data Requirements and Data Interpretation Methods Used in Water Quality Standards and Classification Proceedings**. Water Quality Control Division. August 2004 (CDPHE 2004)

Stream water quality changes attributable to changes in tributary water quality inflows are presented for each basin. Discussion is presented for potentially affected basins where reservoir water quality changes would change water quality downstream of the reservoir.

In general, groundwater quality changes would be negligible to minor (Section 4.6.4) for the majority of the Project area. The South Platte River Basin received greater evaluation due to the alluvial aquifer along the river as it exits the foothills. The South Platte River Basin is highly urbanized from Chatfield Reservoir to Henderson downstream of Denver where the river flow increases (gains) during low flow periods and flow decreases (loses) during high flow periods. Potential impacts from water quality in low flow periods are discussed in relation to possible changes of groundwater flow through potentially contaminated areas. The “15% criteria” for determination of the significance of surface water quality changes stated above also applies groundwater quality changes.

4.6.2.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

4.6.2.1.1 Reservoir Water Quality

Williams Fork Reservoir

Water quality within Williams Fork Reservoir is dependent on upstream water quality from the Williams Fork River, and potential changes in reservoir operations, evaporation, and water surface elevation. Flow into the Williams Fork Reservoir would change very little between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032). Water surface elevation is projected to change between 1 and 4 feet higher between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032). These changes, compared to the overall depth of the reservoir, are not anticipated to cause water quality changes or changes in seasonal turnover.

Dillon Reservoir

Water quality within Dillon Reservoir is dependent on the upstream water quality from the Blue River, and potential changes in reservoir operations, evaporation, and water surface elevation. Water quality of the Blue River inflow or other tributary inflow would change only negligibly under the Proposed Action with RFFAs. Variations in reservoir elevation would be greater and remain at lower levels longer under Full Use with a Project Alternative with RFFAs (2032) compared to Current Conditions (2006). This variation would potentially affect reservoir water quality. Lower elevations and corresponding reduced reservoir volume may increase phosphorus and nitrogen concentrations. This would increase the chlorophyll *a* concentrations and reduce clarity. Future changes in nutrient loadings from WWTPs are not known, however current wording in Regulation 71 promulgated by the CDPHE disallows increases in nutrient loadings. The impact associated with the increased variation in reservoir elevation cannot be explicitly predicted and would be heavily affected by future levels and potential reductions in nutrient loading from WWTPs and non-point sources.

The elevation variations could also drive changes in discharge permits for those permitted discharges into or very near to the reservoir. This change would affect the Town of Frisco WWTP, the Snake River WWTP, and the Farmer’s Korner WWTP. The NPDES permit for the Snake River plant provides for a mixing zone to comply with discharge regulations. With changes in historic reservoir elevations, it is possible that the Snake River plant would be required to meet permit conditions at the end of the discharge pipe rather than at the edge of the mixing zone. Dependent on the Snake River plant's ability to optimize treatment with existing processes, additional processes or process upgrades may be needed. Alternatively, a longer discharge pipe that would provide for discharge into a mixing zone at lower reservoir elevations would be needed. The Town of Frisco and Farmer's Korner WWTPs may also see similar changes in discharge permits due to changes in the mixing zone as a result of projected variations in reservoir elevations. The impact associated with the increased variation in reservoir elevation cannot be explicitly predicted as upgrades to treatment plants may be needed to meet other, unrelated regulations and upgrades may be either structural or process related.

Wolford Mountain Reservoir

Water elevations in Wolford Mountain Reservoir would decrease only slightly between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032). Water quality upstream of Wolford Mountain Reservoir would not be affected by the Proposed Action with RFFAs. Water quality in Wolford Mountain Reservoir would not change due to the Proposed Action with RFFAs.

Gross Reservoir

RFFAs are not likely to have any cumulative effects on water quality at Gross Reservoir beyond those associated with the Moffat Project alternatives, because no major actions that would impact water quality are planned in this area. No new or proposed residential development is projected in the area and private development opportunities are limited since the reservoir is primarily surrounded by U.S. Forest Service land and Boulder County Open Space. Additionally, other development projects in the area would also be required to implement stormwater management measures to minimize impacts to water quality**.**

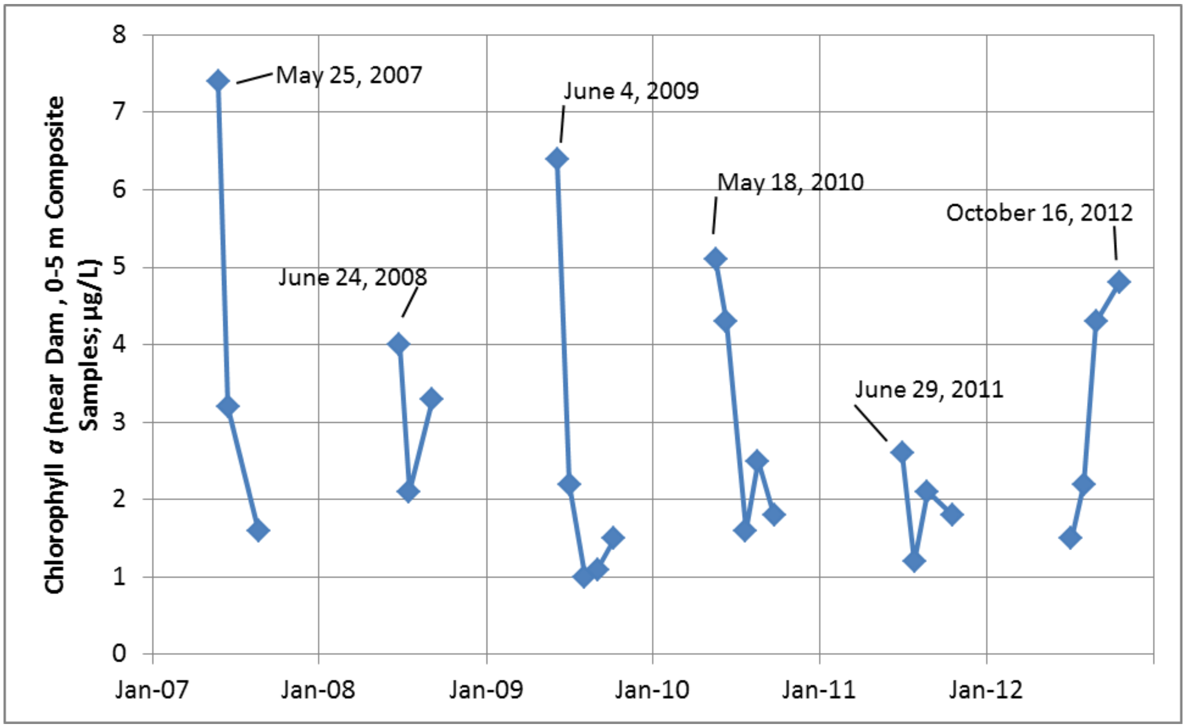
It is anticipated that inundation of new areas could cause minor to moderate changes to water quality during initial filling operations and, potentially, for several years thereafter. These changes could include increased total organic carbon (TOC) concentrations and increased productivity (algal growth). These short-term changes due to inundation of new areas could also include increases in methylmercury (MeHg). This is relevant because Gross Reservoir is currently on the Monitoring and Evaluation List for mercury concentrations in fish tissue (CDPHE 2012a). No long-term adverse impacts were identified for water quality within Gross Reservoir (see the discussion of Aquatic Biological Resources impacts presented separately in Section 4.6.11). Analyses supporting these statements regarding water quality are presented in the following subsections, organized as follows:

- Effects on Trophic State of Gross Reservoir, and
- Effects on MeHg Concentrations.

Effects on Trophic State of Gross Reservoir

Analysis of available data and literature was conducted to evaluate whether the reservoir expansion under the Proposed Action could result in long-term changes to the trophic state of Gross Reservoir. EPA defines trophic state as an indication of the biological productivity of a lake, primarily in the form of algae (http://www.epa.gov/greatlakes/glossary/Glossary.html). Chlorophyll *a* concentrations[1] in Gross Reservoir are generally low, ranging from 1.0 to 7.4 micrograms per liter (µg/L) in recent years, as shown in Figure 4.6.2-1. Gross Reservoir is currently a borderline oligotrophic/mesotrophic system, based on average summertime chlorophyll *a* concentrations compared to the Carlson Trophic Index (Carlson 1977).

Figure 4.6.2-1
Chlorophyll *a* Concentrations Observed in Gross Reservoir, Peak Annual Concentration Dates Noted



To gain an understanding of the potential changes in factors affecting the trophic state of Gross Reservoir that might result from the Proposed Action with RFFAs, anticipated changes to the following two key factors were considered:

- Nutrient Concentrations, and
- Epilimnetic Temperatures.

[1]The highest algal concentrations tend to be observed during the first sampling event (in May or June), which could be a response to inflow of nutrients accompanying snowmelt runoff. Note that the peak occurred later in 2012, a year with minimal snowmelt runoff and a relatively late first sampling event (i.e., July 3). Also note that there is uncertainty about current winter algal dynamics, since sampling tends to cover May through October.

The analysis concludes that long-term productivity in the reservoir would remain the same or decrease as a result of the Proposed Action, thereby causing no eutrophication. Discussions of long-term effects of each of the key factors potentially affecting trophic state are presented below.

Nutrient Concentrations – Nutrients can play an important role in determining productivity and corresponding trophic state of a reservoir. Nutrient concentrations were evaluated by review of inflow concentration through use of the Vollenweider (1976) relationship, and in terms of potential changes to internal loading. All of these analyses suggested that nutrient concentrations in Gross Reservoir would likely remain the same or decrease with the Proposed Action with RFFAs (as compared to Current Conditions). These analyses are described below.

Inflow Nutrients – Inflow nutrient concentration data were reviewed to assess whether the concentrations could be expected to change in the future with changes to relative contributions from South Boulder Creek and the Moffat Tunnel. First, the relative mixture of native South Boulder Creek and Moffat Tunnel inflows to Gross Reservoir is not expected to change greatly. Under Current Conditions (2006), Moffat Tunnel diversions make up approximately 56% of the inflow to Gross Reservoir (average over the entire 45-year PACSM simulation). Under the Proposed Action, Moffat Tunnel diversions would make up approximately 61% of the inflow to Gross Reservoir (average over the entire 45-year PACSM simulation), corresponding to a 5% change. As discussed in Section 3.2, no change in water quality in the Moffat Tunnel, relative to historical conditions, is expected with the Proposed Action. As such, inflow water quality concentration changes (including nutrients) are not anticipated.

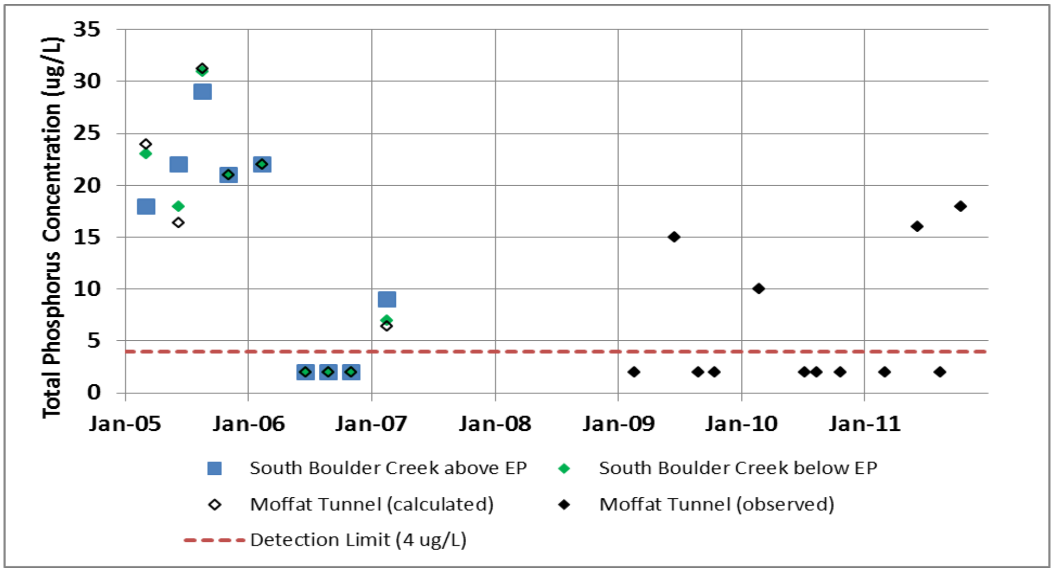
In an effort to assess the potential change in nutrient concentrations more directly, nutrient concentrations for the two sources (Moffat Tunnel water and native South Boulder Creek water) were compared. The available dataset for comparison of nutrient concentrations is somewhat limited. There are no data available for nitrogen concentrations or phosphorus subspecies, so the analysis focused on total phosphorus concentrations. There were 12 measurements of total phosphorus taken directly from the Moffat Tunnel water between 2009 and 2011, but there were no paired measurements of total phosphorus collected on South Boulder Creek upstream of Gross Reservoir on the same days to facilitate comparison. Between 2005 and 2007, however, nine pairs of measurements of total phosphorus were taken on South Boulder Creek just above and below the East Portal of the Moffat Tunnel. Measurements of flow were made at the same time as the total phosphorus measurements, so a mass balance approach was used to estimate Moffat Tunnel phosphorus concentrations. These data, as well as the observations from the Moffat Tunnel between 2009 and 2011, are shown in Figure 4.6.2-2. Non-detect data are plotted at a value equal to half of the detection limit (detection limit = 4 µg/L).

When the concentrations from the nine paired samples are compared statistically (using a two-sample Kolmogorov-Smirnov test[2] with two-sided alternative hypothesis at the 95% level), results indicate that these two sets of measurements are not statistically distinguishable. If the same test is carried out with a one-sided alternative hypothesis to

[2] A two-sample Kolmogorov-Smirnov test is a nonparametric statistical test of two datasets that assesses a null hypothesis that the two datasets are drawn from the same distribution.

analyze the probability that the Moffat Tunnel phosphorus concentrations are higher than those in native South Boulder Creek water, the high p-value (0.89) indicates that there is a very low probability (11% chance) that the Moffat Tunnel concentrations are higher. Inclusion of the non-paired direct measurements made in the Moffat Tunnel between 2009 and 2011 in the Moffat Tunnel dataset (with, or without the mass balance-inferred concentrations) further decreases the probability that Moffat Tunnel phosphorus concentrations are higher than native South Boulder Creek concentrations.

Figure 4.6.2-2
Total Phosphorus Observations from 2005 through 2011
(From the Moffat Tunnel and From South Boulder Creek Near the Moffat Tunnel)



Notes:
"EP" refers to East Portal of the Moffat Tunnel; "calculated" indicates values were determined by mass balance calculations.
µg/L = micrograms per liter

Based on this analysis, there is no statistical difference in nutrient concentrations from the Moffat Tunnel and from native South Boulder Creek flows. Combined with the relatively small anticipated change in mixing ratios (5% increase in the Moffat Tunnel portion of flow into Gross Reservoir), no changes in inflow concentrations are anticipated.

Vollenweider Relationship

Per agency comments received on the Moffat Project Preliminary Final EIS (CDPHE 2012d), the Vollenweider (1976) relationship was applied to estimate changes to in-reservoir phosphorus concentrations with the Proposed Action changes to inflow loading and reservoir size. Vollenweider (1975 and 1976) relationships are not appropriate for application to all systems, and have an underlying assumption of phosphorus limitation when applied to trophic assessment; however, in response to CDPHE requests, these calculations were performed and included in the Final EIS. Assuming an inflow concentration of 14.7 µg/L total phosphorus (based on an average of all data from Pinecliffe from 2009 through 2012, setting non-detect results to half the detection limit), the following relationship was used to estimate in-reservoir phosphorus concentrations for Current Conditions and the Proposed Action with RFFAs:

$$P = \frac{L_p}{q_s}\left[\frac{1}{1+\sqrt{\frac{z}{q_s}}}\right] \times 1000$$

Where:

P = in-reservoir phosphorus concentration (µg/L)

L_p = aerial phosphorus loading rate (grams per square meter per year [$g/m^2/yr$])

q_s = surface overflow rate (z/τ)

τ = hydraulic residence time (year)

z = mean depth (meters)

Note that the areal phosphorus load would decrease with the Proposed Action with RFFAs when compared to Current Conditions (2006), due to a larger reservoir surface area. As shown in Table 4.6.2-1, this simplified approach predicts a small decrease in average phosphorus concentrations in the reservoir under the Proposed Action with RFFAs.

Table 4.6.2-1
Vollenweider Calculations Estimating Relative Change in Phosphorus Concentrations in Gross Reservoir

Parameter	Current Conditions (2006)	Proposed Action with RFFAs (Alternative 1a)
Hydraulic Residence Time (τ, years)	0.25	0.72
Average Depth (z, meters)	27.62	40.28
Surface Overflow Rate (q_s, m/yr)	110.8	56.3
Average Surface Area (m^2)	1,214,100	2,687,208
Areal Phosphorus Load (L_p, $gP/m^2/yr$)	1.6	0.8
In-reservoir Phosphorus Concentration (µg/L)	10	8

Source: Vollenweider, 1975.
Notes:
µg/L = micrograms per liter
$g/m^2/yr$ = grams per square meter per year
m^2 = square meters
m/yr = meter per year

Internal Loading of Nutrients – Internal loading of nutrients occurs when nutrients stored in organic matter and sediments at the bottom of a reservoir are released into the water column. Rates of internal loading increase sharply if anoxic conditions develop at the sediment-water interface. Internal loading rates are also positively correlated with temperature at the sediment-water interface. Increased internal loading of nutrients could affect trophic state by increasing productivity within the reservoir, so the potential for increased internal loading was assessed through consideration of DO concentrations and temperatures at the bottom of the reservoir.

DO profile data are collected in Gross Reservoir; however, the profiles do not extend to the bottom of the reservoir at the location near the dam. Still, though the bottom of the profiles at this location tend to be tens of feet from the sediment-water interface, they are well within the hypolimnion and provide an indication of oxygen conditions at depth. The lowest concentration observed at the deepest point in the profile near the dam was 6.1 milligrams per liter (mg/L) on October 11, 2010, at a depth of 180 feet (55 meters). Based on this and the relatively low productivity of the reservoir as indicated by low chlorophyll *a* concentrations, low DO concentrations at the sediment water interface are not expected to occur. Further, since inflowing organic matter and nutrient concentrations are not expected to increase, there is no expectation that anoxic conditions will develop in the long term with implementation of the Proposed Action with RFFAs.

Results from the hydrodynamic and temperature model of the reservoir (Hawley et al. 2013; presented in Appendix E-5) indicate that temperatures at the sediment-water interface are expected to generally decrease in response to changes associated with the Proposed Action, especially through the months of summer stratification. This decrease in temperature at the bottom of the reservoir could further slow reactions leading to internal loading of nutrients. Based on this analysis, long-term internal loading is expected to remain low or further decrease with implementation of the Proposed Action with RFFAs. Further, with the increased volume of the reservoir for the Proposed Action, any internally-loaded nutrients would be more diluted following turnover, resulting in reduced effects on trophic state for the Proposed Action with RFFAs, relative to Current Conditions.

Epilimnetic Temperature – Changes in epilimnetic temperature could affect the trophic state of Gross Reservoir because algal growth rates can increase with water temperature. Results from the hydrodynamic and temperature model of the reservoir (Hawley et al. 2013; presented in Appendix E-5) were evaluated to assess potential changes to epilimnetic water temperatures. Simulated in-reservoir temperature profiles for the Proposed Action with RFFAs, as compared to Current Conditions show that the key in-reservoir thermal effect of the expansion would be an increase in the depth (and volume) of the hypolimnion during summer stratification. For the Proposed Action expanded reservoir, the depth of the epilimnion did not change, though the timing of onset of stratification and turnover varied. Specifically, stratification tended to begin later for the expanded reservoir, and fall turnover occurred later. The shift in the summer stratification period was on the order of a month or more for the two years simulated. This effect is shown in simulated profiles from the modeling segment adjacent to the dam (Figure 4.6.2-3).

Figure 4.6.2-3
Simulated Profiles for 1971 with 2012 Meteorology, Near Gross Reservoir Dam

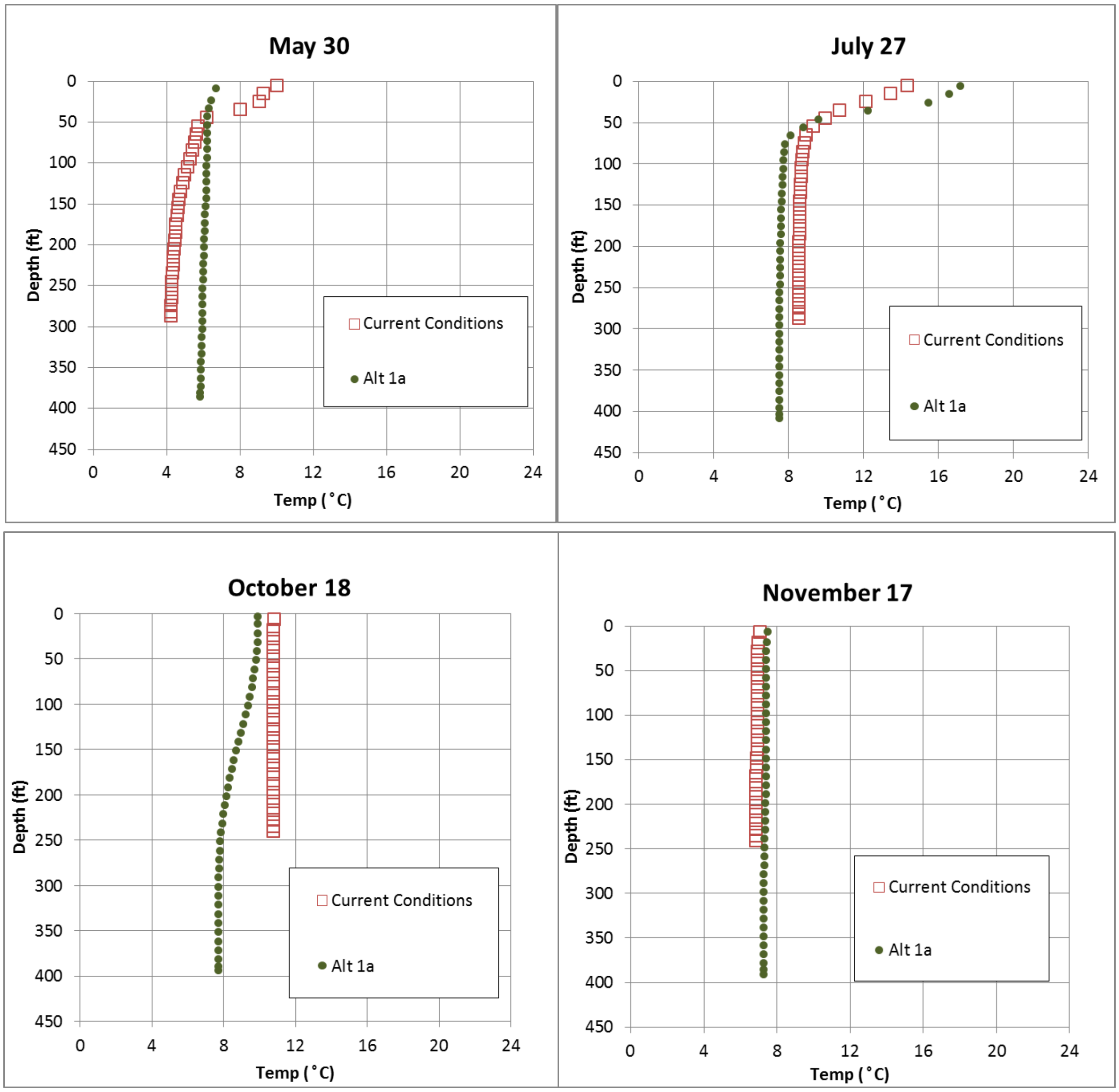
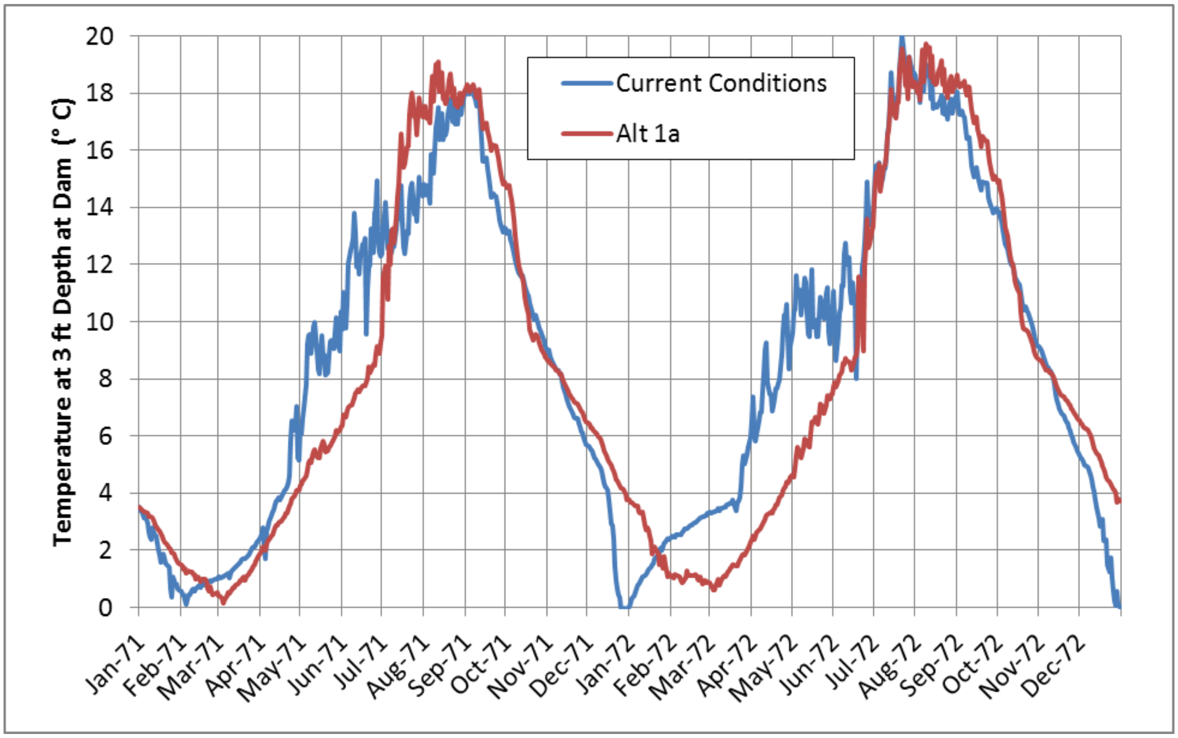


Figure 4.6.2-4 presents the times-series epilimnetic water temperatures for the Current Conditions and Proposed Action with RFFAs simulations. This figure shows that epilimnetic water temperatures are simulated to be cooler for the expanded reservoir from roughly February through June and part of July (covering the period of currently observed peak algal concentrations). In July and part of August, epilimnetic waters could be a couple of degrees warmer or slightly cooler (for the two years simulated). By mid-August through January, epilimnetic waters would be slightly warmer for the Proposed Action with RFFAs as compared to Current Conditions. Peak epilimnion temperatures may change slightly (i.e., increase or decrease from year to year). Based on these findings, there could be a shift in the timing of the peak observed algal concentrations, since temperatures would be cooler

at the top of the reservoir in May and June. Increased algal growth, however, is not expected since peak temperatures change much less than 1 degree Celsius (˚C) (increasing slightly in some years and decreasing slightly in others).

Figure 4.6.2-4
Simulated Gross Reservoir Water Temperature at 3-Foot Depth Near Dam, 1971 and 1972, 2012 Meteorology



Effects on Methylmercury Concentrations – Under the Proposed Action, the full pool footprint of Gross Reservoir would more than double in size. This expansion would inundate currently vegetated areas. As described in Chapter 2, this impact would be minimized by removal of trees and vegetation around the reservoir rim prior to initial filling; however, there would still be some organic material present during filling. This organic material would decay over time following inundation, resulting in consumption of DO, and release of organic matter and nutrients to the reservoir. These inundation effects are expected to minor to moderate, and not expected to exert long-term effects. There is also the potential that inundation of currently vegetated areas could influence mercury methylation (Bodaly 1997).

Gross Reservoir is currently on the Monitoring and Evaluation List for mercury concentration in fish tissue (CDPHE 2012a). Transient increases in mercury concentrations in fish tissues have been observed to peak and then gradually subside following impoundment of new reservoirs (Bodaly 1997). Most mercury in fish tissue is MeHg, so an understanding of the factors that influence MeHg concentrations is important for analysis of potential changes in concentration of mercury in fish tissue. Food web dynamics can also play a role in the accumulation of MeHg in fish. Rates of mercury methylation and demethylation are highly dependent upon redox potential (Compeau 1984). Higher redox potentials tend to result in increased demethylation, and lower redox potentials tend to result in increased methylation. Lower redox potentials in lakes occur primarily in response to increased decomposition of organic matter, so factors affecting rates of organic matter decomposition were considered to assess the potential for long-term effects.

Based on the analysis of long-term trophic state effects (above), organic matter concentrations are expected to remain the same or decrease, and DO minima at the bottom of the reservoir are expected to remain the same or increase. This suggests less favorable long-term conditions for mercury methylation under the Proposed Action with RFFAs, as compared to Current Conditions (2006). In the short term, however, there may be some organic matter present at the bottom of the newly inundated areas, though efforts would be made to minimize the mass of this material as described in Chapter 2. This material would decay and would likely produce conditions conducive to mercury methylation beyond those of the current configuration. As a result, there may be a temporary increase in MeHg concentrations in fish tissue in response to the proposed enlargement. This increase is not expected to be a long-term increase, but instead a temporary, post-inundation phenomenon that peaks in the years following the expansion and subsides over subsequent years. The duration of the effect is uncertain.

Antero Reservoir

Reservoir elevations would remain similar under Full Use with a Project Alternative with RFFAs (2032) as under Current Conditions (2006). Additionally, water quality upstream of Antero Reservoir would not change. Therefore, water quality in Antero Reservoir would not change as a result of the Proposed Action with RFFAs.

Eleven Mile Canyon Reservoir

Reservoir elevations would remain similar under Full Use with a Project Alternative with RFFAs (2032) as under Current Conditions (2006). Additionally, water quality upstream of Eleven Mile Canyon Reservoir would not change. Therefore, water quality in Eleven Mile Canyon Reservoir would not change as a result of the Proposed Action with RFFAs.

Cheesman Reservoir

Reservoir elevations would remain similar under Full Use with a Project Alternative with RFFAs (2032) as under Current Conditions (2006). Additionally, water quality upstream of Cheesman Reservoir would not change. Therefore, water quality in Cheesman Reservoir would not change as a result of the Proposed Action with RFFAs.

Strontia Springs and Chatfield Reservoirs

Water quality within both reservoirs is dependent on upstream water quality from the South Platte River, water deliveries through Roberts Tunnel, and/or changes in reservoir operation, evaporation, and water surface elevation. The South Platte River water quality changes would occur from upstream changes in copper, iron, and nickel content in the North Fork South Platte River. These changes in upstream water quality occur seasonally with yearly loading similar to Current Conditions (2006). Therefore, some changes on a seasonal basis would occur in both reservoirs, but loading changes on an annual basis would not change as compared to Current Conditions (2006).

Strontia Springs Reservoir would have significant changes in end-of-month volume. However the average residence time would be just over a month with little change between Full Use with a Project Alternative with RFFAs (2032) and Current Conditions (2006). Therefore, there would be no change in water quality between Full Use with a Project Alternative with RFFAs (2032) and Current Conditions (2006).

Nitrogen and phosphorus would be the water quality parameters of concern in Chatfield Reservoir. The total annual phosphorus loadings from the South Platte River would increase between Full Use with a Project Alternative with RFFAs (2032) and Current Conditions (2006) due to increases in annual deliveries through Roberts Tunnel. However, the majority of those increased deliveries are diverted to the Foothills Water Treatment Plant (WTP), so the total phosphorus loading would not change substantially. CDPHE Regulation 73 does not include water deliveries through Roberts Tunnel as related to the annual phosphorus loading to Chatfield Reservoir. Any phosphorus loading to North Fork South Platte River through Roberts Tunnel is regulated via Regulation 71, Dillon Reservoir Control Regulation (CDPHE 2007b). Seasonal phosphorus loading would vary due to seasonal changes in deliveries through Roberts Tunnel. Because Chatfield Reservoir is primarily a flood control reservoir with a relatively stable reservoir pool, inflow and outflow variations from historical conditions would not change water quality appreciably from the existing quality.

Granby Reservoir, Shadow Mountain Reservoir, and Grand Lake (Three Lakes)

The methodology used to predict water quality for Granby Reservoir, Shadow Mountain Reservoir, and Grand Lake relied on use of the Three Lakes Water-Quality Model (AMEC 2008). The original model was enhanced and updated for use in the Windy Gap Firming Project (WGFP) and is documented in a separate report (Reclamation 2008). The model was subsequently used to evaluate Current Conditions and Full Use with a Project Alternative with RFFAs (2032). The model, its application for this effort, and model results are described below.

Three Lakes Water-Quality Model

The Three Lakes Water-Quality Model is a dynamic, mechanistic model that simulates water quality on a daily basis. In the model, impacts of inflows, outflows, settling, and constituent transformations are described using differential equations based on lake and reservoir processes. Because the model is mechanistic, versus empirically-based, it can be used to predict water quality conditions under a variety of situations that differ from what has happened historically. The Three Lakes Water-Quality Model has been developed to simulate flow and water quality of Granby Reservoir, Shadow Mountain Reservoir, and Grand Lake in an integrated fashion. This is an important feature because of the interdependencies between the three water bodies and their relation to Colorado-Big Thompson (C-BT) operations.

The Three Lakes Water-Quality Model characterizes Grand Lake and Granby Reservoir as three-layer lakes. Both have an epilimnion, metalimnion, and hypolimnion during the stratified period and the water quality of each layer is assumed to be uniform throughout each layer. The model mixes the three layers during non-stratified portions of the year. The thickness of Granby Reservoir's hypolimnion varies over time as the total content changes. Because the surface water elevation of Grand Lake is constant, the thicknesses of all three layers remain constant.

Although Grand Lake and Granby Reservoir are deep and strongly stratify in the summer, Shadow Mountain Reservoir is shallow and does not strongly stratify because of a high level of periodic mixing (from wind and advection). As such, Shadow Mountain Reservoir is characterized as having a single, well-mixed layer in the model.

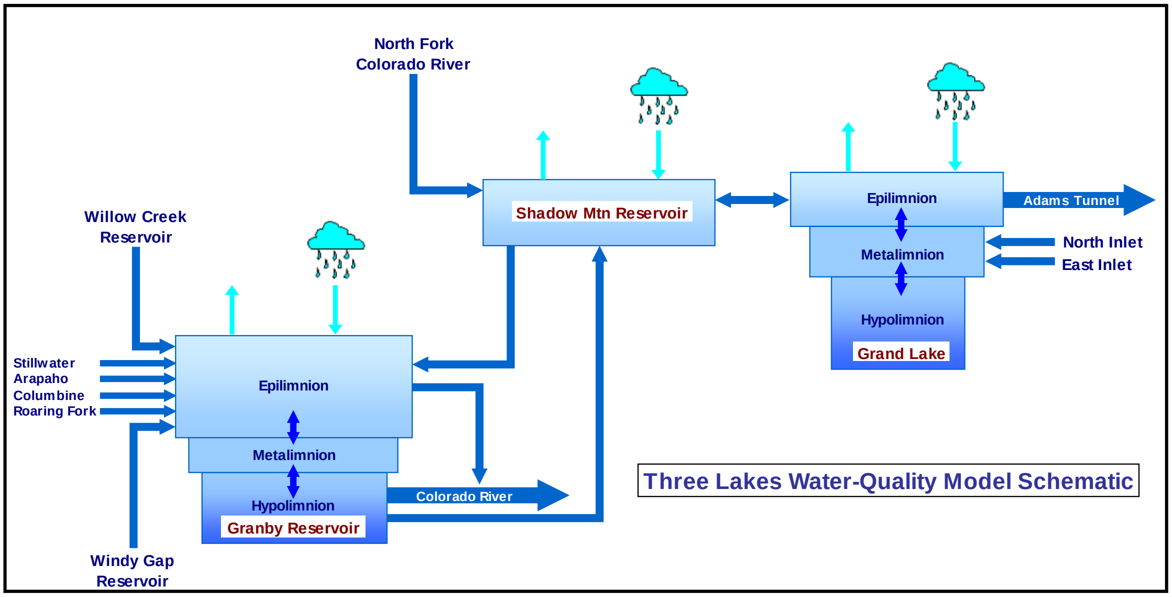
The Three Lakes Water-Quality Model considers inflowing tributaries, water pumped into the system, miscellaneous gains, precipitation, releases and losses from the system, and interflows between the three water bodies. Table 4.6.2-2 lists the modeled inflows and outflows of the Three Lakes system. This list does not include the inter-reservoir flows between the three lakes.

Table 4.6.2-2
Inflows Into and Outflows From the Three Lakes System for the Three Lakes Water-Quality Model

	Granby Reservoir	Shadow Mountain Reservoir	Grand Lake
Inflows	Arapaho Creek Stillwater Creek Roaring Fork Columbine Creek Windy Gap Pump Canal Willow Creek Pump Canal Precipitation Miscellaneous Gains	North Fork Colorado River Precipitation Miscellaneous Gains	North Inlet East Inlet Precipitation Miscellaneous Gains
Outflows	Releases to the Colorado River Evaporation	Evaporation	Outflows to the Adams Tunnel Evaporations

The flows listed in Table 4.6.2-2, along with flows through the Farr Pumping Plant are model variables, entered as an input on a daily basis. Model input also includes the lake layer in which an inflow is entering or an outflow is releasing. The hydrologic portion of the model then performs a mass balance for each reservoir and each layer on a daily basis, accounting for the quantity and direction of flow. The model uses the elevation-area-capacity relationship for Granby Reservoir layer contents. Therefore, although the epilimnion thickness is fixed, the contents of the epilimnion change over time as the surface water elevation varies. The contents of each reservoir and layer are computed on a daily basis. Model segmentation, inflows, and outflows are shown in Figure 4.6.2-5.

Figure 4.6.2-5
Three Lakes Water-Quality Model Schematic



The Three Lakes Water-Quality Model simulates the water quality of each lake or reservoir layer over time on a daily basis. Constituents simulated include:

- Phosphorus – Orthophosphate, organic phosphorus, and total phosphorus;
- Nitrogen – Ammonia, nitrate, organic nitrogen, and total nitrogen;
- Chlorophyll *a;*
- Secchi-disk depth;
- Dissolved oxygen; and
- Total suspended solids.

The majority of the algorithms used in the model are described in Chapra (1997). The details of the algorithms used can be found in AMEC (2008). Major assumptions and limitations of the Three Lakes Water-Quality Model include:

1. Granby Reservoir and Grand Lake can be represented by three homogeneous layers and Shadow Mountain Reservoir can be represented by one homogeneous layer. Therefore, vertical and lateral variations in water quality constituents within a layer cannot be predicted. In addition, all inflows of water and associated water quality constituents entering a layer are instantaneously dispersed throughout that layer.
2. The physical, chemical, and biological dynamics in a lake or reservoir can be described using the principle of conservation of mass. The model considers: (a) mass added by inflows, (b) mass removed via outflows, (c) the diffusion of mass, and (d) changes in concentrations caused by processes such as settling, transformations caused by reactions, growth, respiration, grazing, etc.

3. Complex chemical and biological processes can be represented by equations incorporating simplified kinetic formulations.
4. Simulations are based on average daily conditions. Therefore, changes that occur within a day (e.g., turning a pump on mid-day) cannot be captured.

The model was calibrated using measured data from the period of October 1, 2005, to September 30, 2006. This period was chosen to take advantage of the data collected by U.S. Department of the Interior, Bureau of Reclamation (Reclamation) for the C-BT Nutrient Study (NCWCD 2007). Calibration was based on one index site per water body – GR-DAM for Granby Reservoir; SM-MID for Shadow Mountain Reservoir, and GL-MID for Grand Lake. The calibration process involved determining appropriate parameters such as reaction rates and diffusion coefficients for the Three Lakes. Results from the calibration process can be found in Reclamation (2008).

Model Application

In order to evaluate potential Project impacts, the calibrated model was used to predict water quality conditions for Current Conditions (2006) and for each alternative. Flows were based on PACSM results and methods using historical data for the inflowing tributaries. Inflow concentrations for Stillwater Creek, North Inlet, East Inlet, the North Fork Colorado River, Arapaho Creek, and the Willow Creek Pipeline were estimated using historical median concentrations for the month under consideration. Concentrations for the Roaring Fork and Columbine Creek were assumed to be the same as Arapaho Creek because no data were available for these tributaries and each has a less-developed watershed. Concentrations in the Windy Gap Pipeline were based on a mass balance above Windy Gap Reservoir using predicted concentrations at the mouth of the Fraser River, as determined by the Fraser River Water-Quality Model (see Section 4.6.2.1.2). The Three Lakes Water-Quality Model was used to simulate a 15-year period (WY75-WY89), which was found to be statistically similar to the 47-year simulation period for the WGFP water resource model (Thompson 2005). The smaller time horizon (15 years versus 47 years) was used to reduce model run time.

Model Results – Predicted In-Reservoir Concentrations

Model results are described below. First, predictions of average in-lake/reservoir concentrations are described by hydrologic year type. Second, model results for Shadow Mountain Reservoir DO are translated to estimate impacts in the mixed layer at a location of key concern from a standards assessment perspective (SM-DAM).

Predicted in-reservoir concentrations from the Three Lakes modeling effort are summarized in Table 4.6.2-3. Note that the concept of 'year type' in Table 4.6.2-3 varies slightly from that used in the water resources section of this EIS. Although from a hydrologic standpoint, years are categorized by 'water year' (October-September), the results in this section are reported on a calendar year basis (January-December). This is done because, from a water quality perspective, important dynamics that occur in the later part of the calendar year (into the October-December period) are generally a result of operations and hydrology that occurred in the earlier part of the calendar year. For example, in 1977, the minimum hypolimnetic DO in Grand Lake occurs in early October, before turnover. This minimum concentration is in response to low inflows in the spring/summer of 1977, though low runoff is typically set up by minimal snowfall the preceding winter. If the DO results were reported on a water-year basis, that minimum DO value would be associated with WY1978, an average hydrologic year. Reporting the results on a calendar-year basis maintains a better connection between the causes of the response and the response itself.

Results for nutrients, chlorophyll *a*, DO, total suspended solids, and water clarity are reported below. Using the Carlson Trophic State Index (Carlson 1977) and values in Table 4.6.2-3 for average chlorophyll *a*, all three water bodies would be considered mesotrophic under Current Conditions (2006) and Full Use with a Project Alternative (2032). For all three water bodies in general, percent changes for wet year conditions are the highest. Wet years are also the years with the largest increases in nutrient loads for the Proposed Action as compared with Current Conditions. Although percentage changes are highest for epilimnetic total phosphorus (12 to 35%), the predicted increases are in the 1 to 3 µg/L range.

The importance of nutrient (a causal variable) increases lies in resultant effects on chlorophyll *a* concentrations, DO, concentrations, and water clarity (response variables). Increases in average annual chlorophyll *a* concentrations and average annual peak chlorophyll *a* concentrations are predicted to be less than 1 µg/L for all three water bodies. With respect to hypolimnetic DO, Grand Lake and Shadow Mountain Reservoir are expected to decrease slightly (0.1 mg/L or less than 2%). Average and wet year conditions for Granby Reservoir, however, are expected to result in up to a 12% (0.5 mg/L) decrease in hypolimnetic DO. Secchi depth changes are expected to be highest in Grand Lake, with decreases up to 0.4 meter for an annual average. Annual average Secchi depths in Granby Reservoir and Shadow Mountain Reservoir are predicted to decrease by 0.2 meter or less.

The analysis described above focuses on nutrients, water clarity, DO, and food-web dynamics. A water quality condition of concern in the Three Lakes area not addressed directly though the Three Lakes Water-Quality Model is the level of mercury in fish tissue. Granby Reservoir is on the current Section 303(d) List as being impaired for aquatic life use based on mercury concentrations in fish tissue. Bioaccumulation of MeHg can occur when concentrations of MeHg increases in the water column. It is anticipated that the Proposed Action would not result in any additional loadings of mercury to Granby Reservoir via atmospheric deposition (typically a dominant source to water bodies) or inflowing tributaries. The rate of methylation (the rate of conversion from total mercury to MeHg – the more toxic form), however, could be impacted.

Methylation rates in lakes and reservoirs have been tied to DO concentrations. Low DO can enhance methylation in the sediments, MeHg fluxes from the sediment, and methylation in the water column. Model results (Table 4.6.2-3 below) show a hypolimnetic DO decrease of up to 12% for Granby Reservoir under the Proposed Action with RFFAs.

Results from recent studies conducted in Colorado, however, indicate that increases in nutrients can result in reductions in mercury concentrations in biota (Lepak 2013). Higher nutrient concentrations can result in increases in phytoplankton and zooplankton. A higher amount of biomass is then available to accumulate the mercury. This phenomenon has been referred to as "bloom dilution" (Pickhardt et al. 2002; Chen and Folt 2005). The Proposed Action is predicted to result in increased nutrient concentrations in Granby Reservoir (Table 4.6.2-3 below).

Table 4.6.2-3
Model Results for the Three Lakes System
(Calendar Years 1975 to 1988[1])

Year Type	Grand Lake			Shadow Mountain Reservoir			Granby Reservoir		
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	Percent Change	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	Percent Change	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	Percent Change
Average Epilimnetic Total Nitrogen (µg/L)									
Average Year	258	273	6%	278	298	7%	296	321	8%
Dry Year	279	292	5%	298	314	5%	304	321	6%
Wet Year	241	254	6%	262	280	7%	295	321	9%
Average Epilimnetic Total Phosphorus (µg/L)									
Average Year	6	8	24%	10	13	22%	11	13	24%
Dry Year	8	9	14%	12	13	12%	10	12	14%
Wet Year	5	7	25%	9	12	25%	10	14	35%
Average of Annual Minimum Dissolved Oxygen (mg/L) at Bottom[2]									
Average Year	5.9	5.9	-1%	7.1	7.1	-1%	4.2	3.9	-8%
Dry Year	6.5	6.4	0%	7.0	6.9	-1%	4.7	4.7	1%
Wet Year	5.3	5.2	-1%	7.1	7.1	0%	4.5	4.0	-12%
Average Epilimnetic Chlorophyll *a* (µg/L)									
Average Year	3.5	3.9	12%	4.1	4.3	5%	3.1	3.2	2%
Dry Year	3.8	4.0	6%	4.1	4.2	1%	3.3	3.3	0%
Wet Year	3.2	3.8	17%	4.0	4.4	9%	3.2	3.3	3%
Average of Annual Maximum Epilimnetic Chlorophyll *a* (µg/L)									
Average Year	4.9	5.6	12%	5.6	6.2	11%	4.6	4.8	3%
Dry Year	5.0	5.2	4%	5.6	5.8	3%	4.7	4.8	2%
Wet Year	4.2	5.1	23%	6.1	7.0	16%	4.9	5.1	6%
Average Epilimnetic Total Suspended Solids (mg/L)									
Average Year	1.6	1.8	8%	1.8	2.0	7%	2.3	2.5	9%
Dry Year	1.8	1.9	5%	2.1	2.1	2%	2.4	2.5	3%
Wet Year	1.8	1.9	5%	2.0	2.2	6%	2.5	2.6	6%

Table 4.6.2-3 (continued)
Model Results for the Three Lakes System
(Calendar Years 1975 to 1988[1])

Year Type	Grand Lake			Shadow Mountain Reservoir			Granby Reservoir		
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	Percent Change	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	Percent Change	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	Percent Change
Average Secchi-Disk Depth (meters)									
Average Year	3.5	3.2	-8%	2.4	2.3	-3%	4.1	3.9	-4%
Dry Year	3.2	3.1	-4%	2.3	2.3	-1%	3.9	3.8	-1%
Wet Year	3.6	3.2	-12%	2.4	2.3	-4%	3.8	3.7	-3%

Notes:
[1]PACSM for the Environmental Impact Statement used water years 1946-1990.
[2]Dissolved oxygen results for Shadow Mountain Reservoir represent minimum of entire depth, since the reservoir is represented by a single layer in the model.
µg/L = micrograms per liter
% = percent
mg/L = milligrams per liter
PACSM = Platte and Colorado Simulation Model
RFFA = reasonably foreseeable future action

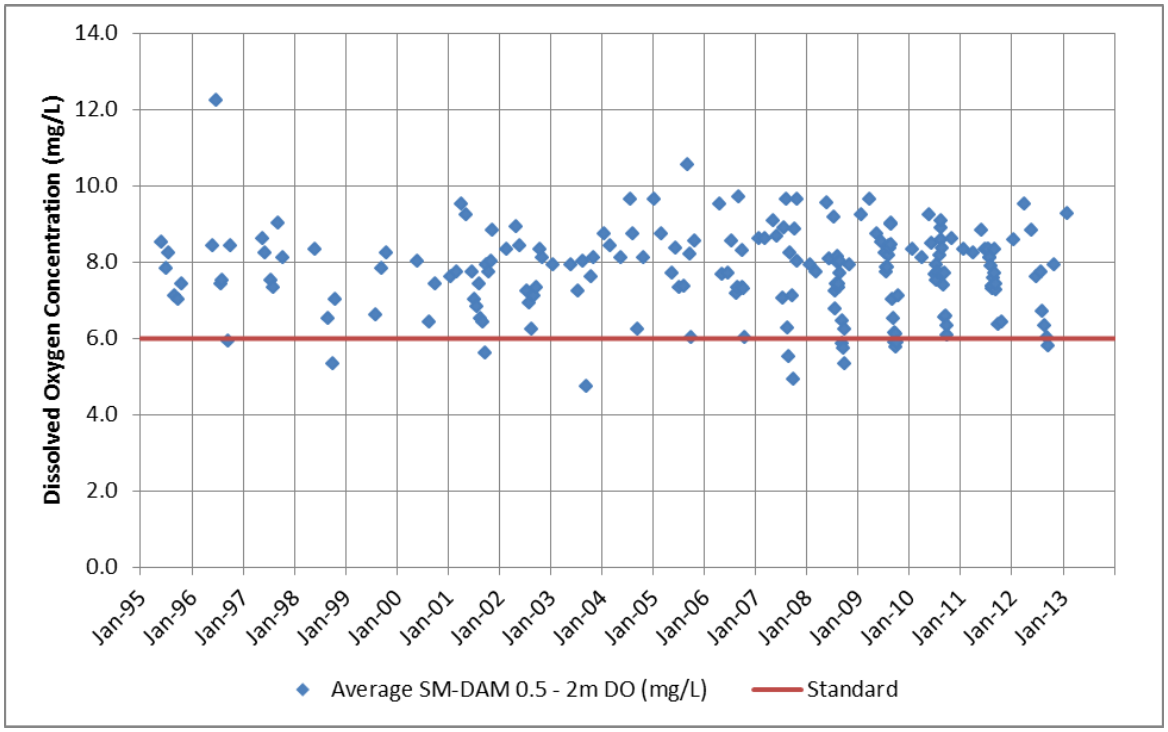
Based on the dynamics described above, it is unclear what the net effect of lower DO (which could increase the rate of methylation) and higher nutrients (which could reduce mercury in sport fish through bloom dilution) would have on mercury concentrations in fish tissue in Granby Reservoir.

The anticipated impacts for all three water bodies are predicted to be minor (in dry and most average years) to moderate, in wet years and some average years. This is based on predicted increases in chlorophyll *a* in Grand Lake (up to a 0.6 µg/L increase in the annual average) and Shadow Mountain Reservoir (up to a 0.9 µg/L increase in the annual peaks); decreases in Secchi depth in Grand Lake (up to a 0.4 meter decrease); and decreases in minimum DO concentrations in Shadow Mountain Reservoir (up to a 0.8 mg/L decrease at SM-DAM site [see the next section]) and Granby Reservoir (up to a 0.5 mg/L decrease). Note that Shadow Mountain Reservoir is currently listed on the Section 303(d) List for being impaired with respect to DO and the Proposed Action with RFFAs would adversely affect this existing DO impairment.

Predictions for Shadow Mountain Reservoir Dissolved Oxygen at SM-DAM

The complex hydrodynamics and water quality dynamics of the Three Lakes system result in spatial differences in seasonal patterns of DO concentration in Shadow Mountain Reservoir. A mechanistic explanation of the underlying causes for these seasonal differences is given in the 2011 Operational and Water Quality Summary Report for the Three Lakes (Boyer and Hawley 2013). A result of these differences in dynamics is that DO concentrations in the 0.5 to 2 meters stratum at the SM-DAM measurement location can sometimes be significantly lower than concentrations at the SM-MID location. The lower concentrations in the upper stratum at the SM-DAM location occasionally exceed the 6.0 mg/L DO standard. Averaged observed DO concentrations in the 0.5 to 2 meters stratum at the SM-DAM location, along with the applicable standard, are shown in Figure 4.6.2-6.

Figure 4.6.2-6
Average Dissolved Oxygen Concentrations in Shadow Mountain Reservoir at Site SM-DAM (0.5 to 2 meters depth)



Concern was expressed by EPA that the impairment reflected in the SM-DAM data is not represented in output from the Three Lakes Water-Quality Model. This is due to the representation of Shadow Mountain Reservoir as a single, well-mixed water body in the model and the fact that the DO response of the reservoir was calibrated to observations made at the SM-MID measurement location. In order to respond to this concern, the following method for interpretation of model results was developed, based on relevant observed data.

The method selected for model result interpretation was development of multiple-regression equations, using observed data that correspond to calibrated model output to predict observed 0.5 to 2 meters average DO concentrations at SM-DAM. Exploratory regression analysis led to differentiation of three separate predictive categories, corresponding to three unique regimes of DO dynamics at the SM-DAM location:

1. No Farr pumping
2. Farr pumping during the months November-June
3. Farr pumping during the months July-October

These three predictive categories were chosen using guidance provided by Boyer and Hawley (2013). The temporal segmentation of the Farr-on categories was validated through comparison of correlation coefficients using slightly different time periods for separation of categories. Throughout the development of the regression equations, emphasis was given to physical relevancy of predictor coefficients (e.g., rejection of a regression equation with a negative coefficient for the SM-MID DO predictor, even if that equation produced a higher correlation coefficient). The final results of this regression analysis are summarized in Table 4.6.2-4.

Table 4.6.2-4
Regression Equation Coefficients

Category	Intercept (mg/L)	SM-MID VWA DO Coefficient (d-less)	GR-DAM VWA Hypolimnetic DO Coefficient (d-less)	SM-MID Chla Coefficient (mg/µg)	Daily Pump Volume Coefficient (mg/L-AF)	Days Since Pumps Off Coefficient (mg/L-day)
Pumps Off	2.69	0.707	N/A	N/A	N/A	-5.601 E-3
Pumps On (November-June)	0.07	0.892	N/A	0.135	7.725 E-4	N/A
Pumps On (July-October)	0.69	0.598	0.508	0.041	-1.196 E-3	N/A

Notes:
Chla = chlorophyll *a*
d-less = dimensionless
DO = dissolved oxygen
E = 10^
mg/µg = milligrams/micrograms
mg/L = milligrams per liter
mg/L-AF = milligrams per liter per acre-feet
mg/L-day = milligrams per liter per day
N/A = indicates term was not used in given regression equation; therefore, no coefficient is provided
VWA = volume-weighted average

In Table 4.6.2-4, these coefficients are multiplied by predictor variables of the same name as the coefficients (units of [dimensionless], [mg/L], [mg/L], [µg/L], [AF/day], [days] respectively) and summed to produce a daily prediction of SM-DAM 0.5 to 2 meters average DO. The results of application of this method for the period 2005-2012 (period of available observed predictor data) are displayed on Figure 4.6.2-7 and Figure 4.6.2-8. The predictions are generally good (especially for the years 2009 and 2010) and are considered to be valuable for model result interpretation. Note, however, that the methodology tends to over-predict minimum DO concentrations at SM-DAM.

Figure 4.6.2-7
Observed and Predicted Dissolved Oxygen at SM-DAM (0.5 to 2 meters average)

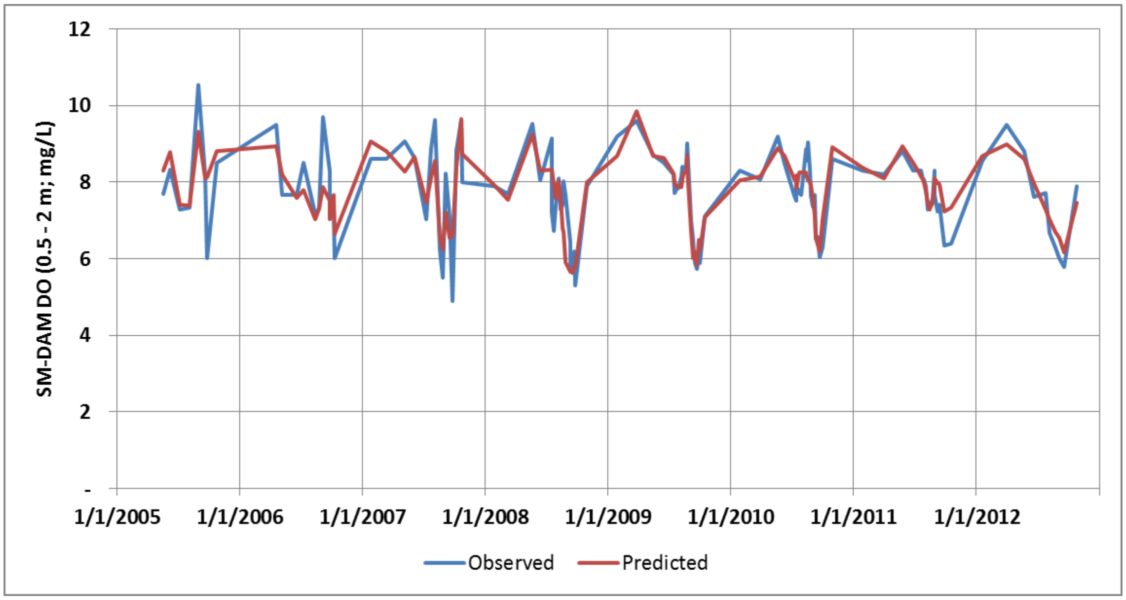
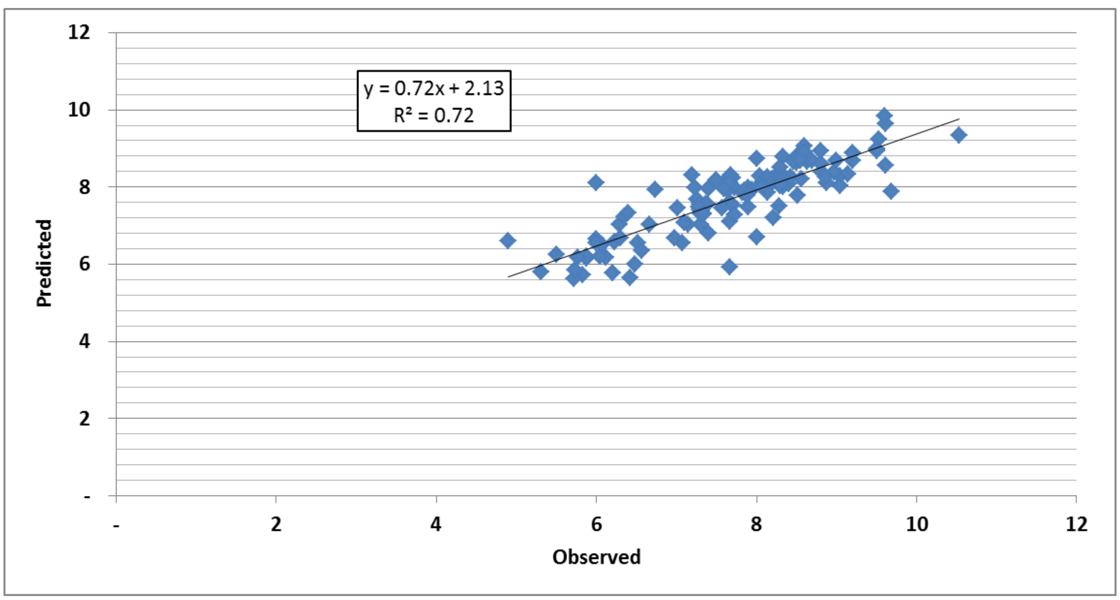


Figure 4.6.2-8
Correlation between Observed and Predicted SM-DAM Dissolved Oxygen (0.5 to 2 meters average)



Using the methodology described above, results from the Three Lakes Water-Quality Model were used to predict DO concentrations at the SM-DAM site (0.5 to 2 meters depth). Results for Current Conditions (2006) and the Proposed Action with RFFAs are shown in Figure 4.6.2-9. For Current Conditions, predicted concentrations over the 15-year period are above the 6 mg/L standard with the exception of the late fall of 1978. This year followed the 1977 dry year and the WGFP was operated to re-fill Granby Reservoir. Thus, Windy Gap diversions and inflows from the Willow Creek Pipeline were high (both greater than 50,000 AF). This resulted in lower than normal DO concentrations near the bottom of Granby Reservoir, resulting in lower than normal DO concentrations in Shadow Mountain Reservoir. For the Proposed Action with RFFAs, DO concentrations decrease even further during that year. Minimum predicted DO concentrations are reported in Table 4.6.2-5 by calendar year, showing decreases in minimum DO concentrations for the Proposed Action. The largest difference between the two scenarios occurs in 1978. This is also the year with the largest change in Farr pumping for the 15-year period simulated.

This information needs to be interpreted knowing the method somewhat over-predicts minimum annual DO concentrations (see Figure 4.6.2-9), and thus most likely under-predicts the probable occurrence of standard exceedances. The differences listed in Table 4.6.2-5 are viewed to be more characteristic of what would happen under the assumed conditions, as opposed to the absolute numbers predicted. The average change in minimum DO concentrations (0.5 to 2 meters depth) for the 15-year period is predicted to be a decrease of 0.25 mg/L, ranging from a decrease of 0.80 mg/L in 1978 to an increase of 0.24 mg/L in 1984.

Figure 4.6.2-9
Predicted SM-DAM DO Concentrations (0.5 to 2 meters average)

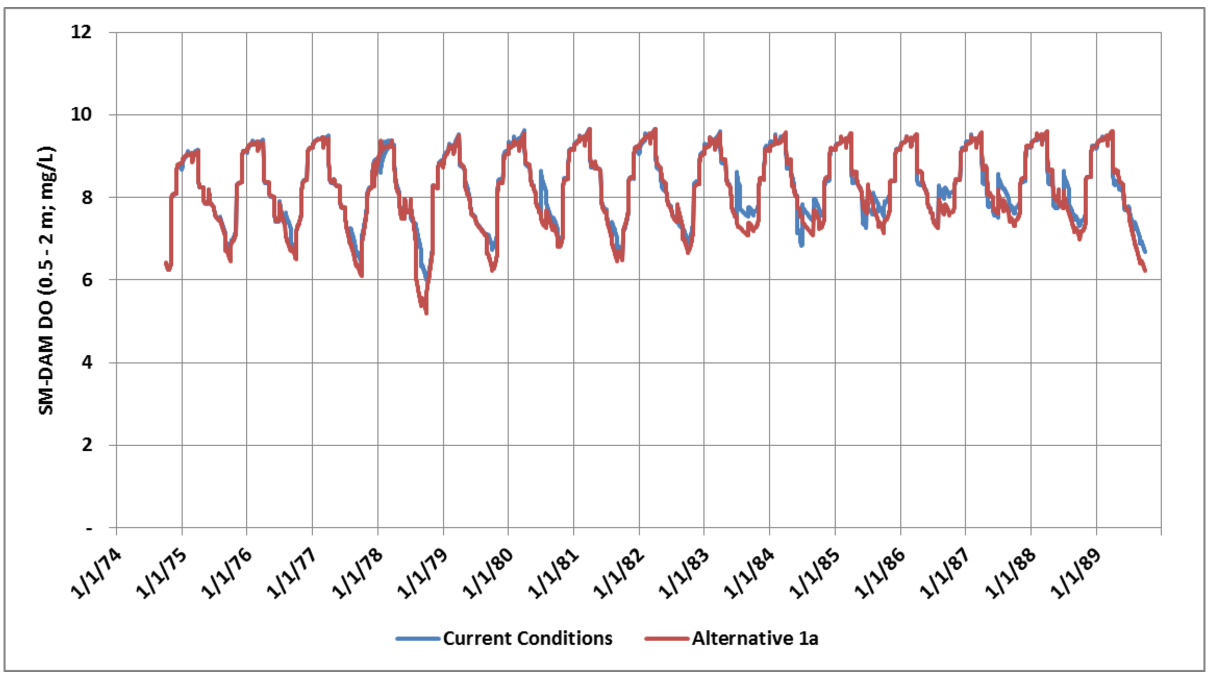


Table 4.6.2-5
Predicted Minimum SM-DAM DO Concentrations (0.5 to 2 meters)

Calendar Year	Minimum Predicted Dissolved Oxygen (mg/L) at SM-DAM (0.5 to 2 meters)		
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	Difference
1975	6.61	6.46	-0.15
1976	6.59	6.50	-0.08
1977	6.42	6.11	-0.31
1978	6.00	5.20	-0.80
1979	6.74	6.23	-0.51
1980	6.91	6.81	-0.11
1981	6.59	6.46	-0.12
1982	6.90	6.66	-0.24
1983	7.53	7.08	-0.45
1984	6.84	7.08	0.25
1985	7.25	7.13	-0.12
1986	7.27	7.25	-0.01
1987	7.52	7.31	-0.21
1988	7.30	6.99	-0.30
1989	6.68	6.22	-0.46

Notes:
mg/L = milligrams per liter
RFFA = reasonably foreseeable future action

4.6.2.1.2 River Segments

Fraser River

The Proposed Action with RFFAs may have potential water quality impacts in the Fraser River Basin including:

a) Changes in Concentrations of Constituents Potentially Exceeding Stream Standards (Copper, Iron, Lead, pH, and Aquatic Life Use): These include changes in contaminant concentrations that would result in moving from the Monitoring and Evaluation List to the Section 303(d) List requiring a TMDL.

***b) Potential Changes in Water Temperature*:**

- Increased frequency of temperature standard exceedance downstream of the Town of Fraser, a segment currently on the Section 303(d) List for temperature.
- Increased frequency of temperature standard exceedance in Ranch Creek, a segment currently on the Section 303(d) List for temperature.
- Increased frequency of temperature standard exceedance in St. Louis Creek.

c) Permit Compliance for Moffat Railroad Tunnel Discharges: Dilution decreases in the Moffat Tunnel permitted discharge would increase contaminant concentrations to potentially harmful levels.

d) ***Potential Changes in Nutrient Levels***

e) ***Potential Impacts to WWTP Dischargers***: The Proposed Action with RFFAs may lead to more stringent discharge permits and possible capital expenditures for WWTPs due to changes in stream flow that reduce dilutive capability or diminish the quality of the receiving water.

f) ***Effects Due to Changes in Tributary Flows and Water Quality***

g) ***Effects on Vasquez Creek Caused by Increased Flows through the Gumlick Tunnel***: These changes could occur as a result of greater contributions from Williams Fork diversions.

Each of these potential water quality impacts is discussed in detail in subsequent subsections.

a) ***Changes in Concentrations of Constituents Potentially Exceeding Stream Standards (Copper, Iron, Lead, pH, and Aquatic Life Use)***

The Fraser River is listed on the Monitoring and Evaluation List for copper from the Town of Fraser to the confluence of the Colorado River and for lead from the Town of Tabernash to the Town of Granby (CDPHE 2012a). As Table 3.2-5 shows, one monitoring station indicates an 85th percentile value for copper greater than the stream standard at the Town of Fraser. Additionally, two CDPHE stations and four U.S. Geological Survey (USGS) stations have records on copper concentrations beginning in 2000. There have been two exceedances of the acute standard for copper on the Fraser River, which occurred on January 25, 2006 and May 5, 2010 at the Water Quality Control Division's (WQCD's) station 12166 (Hranac 2013). The source of the copper is unknown. A majority (131 of 160 samples) of CDPHE samples were below detection limits indicating low levels of copper under most conditions. Without knowing the source(s) of copper that caused the single spikes in copper concentrations at each station, impacts from Full Use with a Project Alternative with RFFAs (2032) cannot be numerically quantified. Potential changes in copper concentrations that could exacerbate the underlying conditions leading to the listing on the Monitoring and Evaluation List, particularly upstream of the Town of Fraser, include: (1) a decrease in dilution water for NPDES permitted discharges (particularly the Moffat Tunnel), and (2) a change in volume of source waters. The sample sites that indicated a high level of copper on one occasion were near Robber's Roost campground and near Winter Park. These occurrences suggest that the source of copper is above most tributaries and above the Moffat Tunnel discharge. As described below, none of these occurrences would be caused by the Moffat Tunnel permitted discharge. The current permit for the Moffat Tunnel would begin to limit copper discharges starting May 1, 2013, which may serve to reduce or eliminate occurrences of copper exceeding the stream standard. If the source of copper is high in the watershed, the copper would be diverted with flows entering the Moffat Tunnel.

The Fraser River from the Town of Granby to the Town of Tabernash is listed on the Monitoring and Evaluation List for lead due to the 85th percentile concentrations at one station (River Watch 806, Fraser River at County Road [CR] 83) being greater than the stream standard. CDPHE stated, "due to quality assurance/quality control issues with some of the lead samples, there was not enough data to make an impairment decision, so it will be added to the Monitoring and Evaluation List in order to gather more information" (CDPHE 2012c). Subsequent data at the same station (through September 2011) indicates all samples were below detection limits (EPA 2012). Additionally, nearby stations, as listed in Table 3.2-5, indicate lead concentrations below the stream standard. The source of lead, if any, is unknown. The current discharge permit for the Moffat Tunnel would begin to limit lead discharges starting May 1, 2013, which may serve to reduce concentrations of lead in the Fraser River. It is noted that the three water districts that provide water to areas served by the Fraser Sanitation District Wastewater Treatment Facility have lead levels greater than the stream standard (but less than the drinking water standard). The source of lead in drinking water systems is typically leaching of lead from indoor plumbing fixtures. If this is the source of lead concentrations greater than stream standards, then Full Use with a Project Alternative with RFFAs (2032) conditions could increase the concentration of lead by greater water use in the Fraser River Basin (with associated greater wastewater flows) and a reduction of stream flow as noted in Section 4.6.2. Therefore, it is not currently known if lead concentrations are above stream standards. The source of the lead is also unknown. There is potential for Full Use with a Project Alternative with RFFAs (2032) conditions to increase the concentration of lead.

The three stations also indicate 85th percentile dissolved iron concentrations greater than the stream standard. This stream standard for iron is set to be protective of drinking water supplies and is set at the recommended maximum concentration for secondary contaminants as set by the EPA. Iron can be removed using conventional water treatment processes. From analysis of the data, the total recoverable iron at these three specific sites is well below the stream standard for total recoverable iron; however, dissolved iron is greater than the stream standard. As with copper, the source of the iron is unknown. Copper was above the stream standard at Robbers Roost, upstream of known point sources, implying a natural source or source high in the watershed. As with copper, if the source of iron is high in the watershed, the iron would be diverted with flows entering the Moffat Tunnel. The Moffat Tunnel permitted discharge would also have a limit on dissolved iron starting May 1, 2013, which may reduce iron concentrations at downstream locations. If the source of iron near Granby is permitted discharges, flow decreases between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) could contribute to dissolved iron concentrations continuing to exceed the stream standard. This would lead to either a limit on dissolved iron in future renewals of NPDES permits or a need by drinking water providers that use the Fraser River to install iron removal provisions in their treatment plants. Since the source of the iron is unknown, the potential impacts cannot be definitively determined.

As noted in Section 3.2, the 85th percentile for pH exceeds stream standards at two sampling locations. This segment was not listed for pH in Regulation 93 (CPHE 2012a) because the 85th percentile for all data sites combined was within stream standards. The source of high pH at these two locations is unknown. Data from USGS for Site 9027100 indicates that pH has exceeded stream standards since 1990. As the source of elevated pH values is unknown, the potential impacts cannot be numerically quantified.

The Fraser River from the source to a point immediately below the Rendezvous Bridge and Vasquez Creek are provisionally listed on the Section 303(d) List for Aquatic Life Use

(CDPHE 2012a). A discussion of the Aquatic Life Use listing and potential impacts related to the Moffat Project is presented in Section 4.6.11.

b) Potential Changes in Water Temperature

In Section 3.2, many reaches of the Fraser River were identified with exceedances of State water quality standards for temperature. Fraser River segment 10c is listed on the Section 303(d) List for temperature (CDPHE 2012a). Ranch Creek is also on the Section 303(d) List for temperature. The evaluation of potential changes in water temperature progressed in a three-step process as initial information was reviewed with the Cooperating Agencies during the Draft EIS comment period and it was determined that additional assessment was warranted, as follows:

1. Identification of stream reaches of most concern based on historic water temperature data.
2. Evaluation of statistical relationships between: (a) stream temperature and stream flow, and (b) stream temperature and air temperature to determine whether either flow or air temperature could be used individually to predict changes in stream temperature.
3. Additional analysis of the three stream reaches with previous exceedances of stream temperature standards (two reaches of the Fraser River and one reach of Ranch Creek) to determine whether statistical relationships between stream temperature and stream flow is improved by isolating the analyses for narrow bands of air temperature.

To evaluate the Fraser River and Ranch Creek stream segments with previous temperature exceedances and also identify other stream segments where water temperatures may approach or exceed standards potentially due to the Proposed Action with RFFAs, information was developed with temperature measurements near or exceeding the standard (within 1°C). Grand County Water Information Network (GCWIN) stations were used since these stations record temperatures every 15 to 60 minutes during summer months. Based on the historical record of daily maximum (DM) and maximum weekly average temperature (MWAT) exceedances in the Fraser River Basin, it is possible that such exceedances could occur in the future during periods when diversions related to the Proposed Action would be taking place.

State regulations provide for an exemption to exceedances of water quality standards when air temperature is greater than the historic 90th percentile for a given day (hereafter referred to as the historic 90th percentile). However, for purposes of considering the potential for the Proposed Action with RFFAs to cause potential exceedances of the temperature standards, this information was not screened to exclude days for which air temperature was greater than the historic 90th percentile value. This information is presented in Table 4.6.2-6.

Table 4.6.2-6
Temperature at GCWIN Stations in the Fraser River Basin (yearly data recording begins between April and July and ends between September and November)

Station	Period of Record	Daily Maximum				Maximum Weekly Average Temperature			
		No. of Days Exceed State Std.	No. of Days within 1°C of State Std.	Max. of Daily Max. °C	State Std. °C	No. of Weeks Exceed State Std.	No. of Weeks within 1°C of State Std.	MWAT (for Period of Record) °C	State Std. °C
Ranch Creek below CR 8315	***2005-2009***	***55***	***33***	***24.3***	***21.2***	***1***	***6***	***17.2***	***17.0***
Ranch Creek below Meadow Creek	***2007-2009***	***36***	***31***	***23.7***	***21.2***	***2***	***5***	***17.3***	***17.0***
St. Louis Creek above Fraser River confluence	***2007-2009***	***2***	***1***	***21.5***	***21.2***	***0***	***0***	***15.4***	***17.0***
Vasquez Creek at Winter Park	2005-2009	0	0	16.9	21.2	0	0	12.9	17.0
Fraser River above WPSD	2007-2009	0	0	16.9	21.2	0	0	11.4	17.0
Fraser River below Winter Park (ski area)	2007-2009	0	0	18.1	21.2	0	0	12.2	17.0
Fraser River at Rendezvous Bridge	2008-2009	0	0	15.5	23.8	0	0	11.6	18.2
Fraser River at CR8HD	2006-2009	0	0	21.9	23.8	0	0	16.5	18.2
Fraser River above FSD	2007-2009	0	0	20.2	23.8	0	0	14.9	18.2
Fraser River below FSD at Pietz	2005	0	0	20.3	23.8	0	0	14.2	18.2
Fraser River below FSD	2007-2009	0	0	20.3	23.8	0	0	15.0	18.2
Fraser River at CR 83	***2005-2009***	***2***	***0***	***24.7***	***23.8***	***0***	***0***	***16.7***	***18.2***
Fraser River below Crooked Creek	***2006***	***0***	***0***	***22.7***	***23.8***	***0***	***1***	***17.8***	***18.2***
Fraser River at Hwy 40 at Granby	***2005-2009***	***0***	***8***	***23.6***	***23.8***	***0***	***9***	***18.1***	***18.2***
Fraser River above GSD	2008-2009	0	0	20.8	23.8	0	0	16.2	18.2
Fraser River below GSD	2008-2009	0	0	22.1	23.8	0	0	15.7	18.2

Notes:
Stream reaches that are near or above the regulatory standard (Regulation 33) are bold and italicized.
CR = County Road
FSD = Fraser Sanitation District
GSD = Granby Sanitation District
WPSD = Winter Park Sanitation District

The six stream reaches (two on Ranch Creek, one on St. Louis Creek, and three on the Fraser River) with at least one temperature measurement near or above the regulatory standard (Regulation 33) are listed in bold italics in the table above and are discussed below. Following those discussions, an evaluation of the relationships between stream flow and stream temperature, and air temperature and stream temperature, is presented.

- **Ranch Creek** – Both GCWIN stations on Ranch Creek indicate numerous samplings that approach or exceed the regulatory standard. Both stations are on the lower reach of Ranch Creek, a broad, open valley with a stream slope of 0.7% (Grand County 2010).

  Some recordings of DM and MWAT that approach or exceed the regulatory standard occurred on days where the air temperature was recorded at or above the historical 90th percentile. However, not all days with high stream temperature occurred on especially hot days. Ranch Creek is evaluated in more detail below.

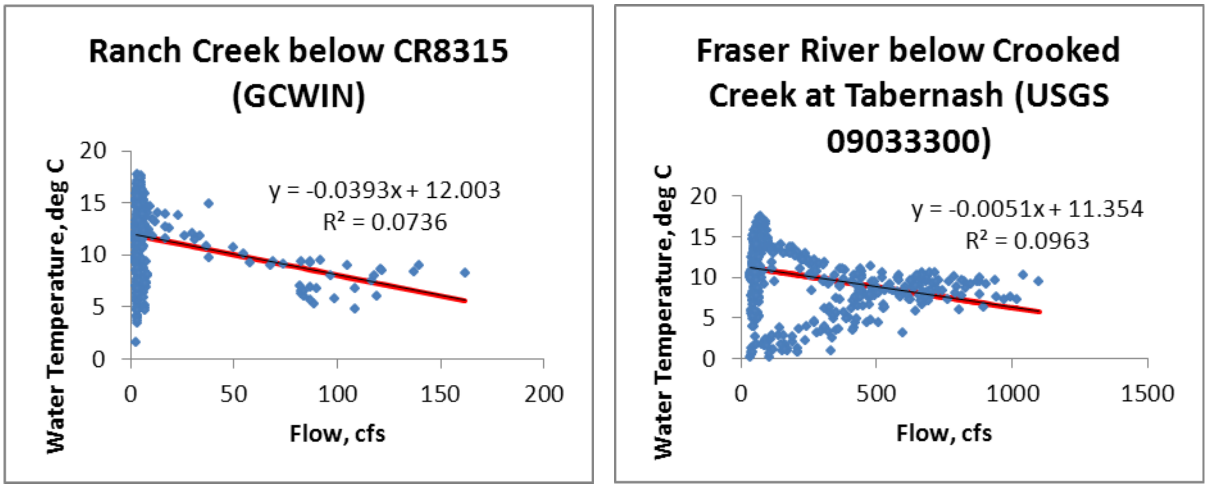
- **St. Louis Creek** – This station is near the confluence of the Fraser River. Two occurrences of temperature approaching or exceeding the regulatory standard occurred on days that the air temperature was equal to or exceeded the historical 90th percentile. Based on this data, St. Louis Creek is not further evaluated for potential stream temperatures exceeding regulatory standards under the Proposed Action with RFFAs.

- **Fraser River** – The Fraser River from CR 83 (just above the confluence with Ranch Creek) to U.S. Highway (US) 40 in Granby (just upstream of downtown Granby) had two instances where the DM regulatory standard was exceeded and a few occasions where both the DM and the MWAT approached the regulatory standard. CR 83 station had two instances of stream temperature exceeding the regulatory standard and both occurred on days when the air temperature exceeded the historic 90th percentile. The station below Crooked Creek recorded one instance of the MWAT approaching the regulatory standard during a week where the air temperature exceeded the historic 90th percentile for 5 consecutive days. The station at US 40 had 5 of the 8 days where the DM approached the regulatory standard with air temperature for that day and/or the preceding days exceeding the historic 90th percentile. Similarly, 3 of the 9 days when the MWAT approached the regulatory standard coincided with a period of several weeks with the air temperature exceeding the historic 90th percentile. Of the three stations on the Fraser River that recorded temperature exceedances, only one station has instances of high stream temperatures on days where the air temperature did not reach the historic 90th percentile. The Fraser River is currently on the Regulation 93 listing and is evaluated in more detail below.

The second step in the assessment of potential effects on stream temperatures was performed in response to Cooperating Agency comments to evaluate statistical relationships between: (a) stream temperature and flow, and (b) stream temperature and air temperature to determine whether stream flow could be used as a basis to predict changes in stream temperature for the Ranch Creek and Fraser River stream segments.

Figure 4.6.2-10 shows flow versus water temperature for Ranch Creek below CR 8315 and the Fraser River below Crooked Creek at Tabernash plotted to determine the degree of correlation.

Figure 4.6.2-10
Flow Versus Water Temperature in the Fraser River Basin
Section 303(d) Listed Stream Segments



For each graphic in Figure 4.6.2-10, spreadsheet functions were used to compute the equation for the linear regression line of best fit and the corresponding R-squared value. A trend line slope of zero indicates there is no correlation between water temperature and flow rate for a given air temperature. A positive slope indicates that water temperature increases with stream flow (i.e., positive correlation). A negative slope (as shown in each graphic in Figure 4.6.2-1) indicates that water temperature decreases with stream flow (i.e., negative correlation). As the absolute value of the slope increases, the relationship between flow and stream temperature becomes sensitive.

R-squared is a parameter that measures the degree to which the data deviates from the line of best fit. R-squared can range from 0 to 1, with "0" indicating extreme deviation of data points from the line of best fit, and "1" indicating no deviation of data points from the line of best fit. The R-squared value provides an indication of the quality of the trend line with regard to how well it represents the relationship between, in this case, stream flow and water temperature. A low R-squared value indicates the trend line does not provide a reliable representation of a potential cause-and-effect relationship. The slope provides an indication of the correlation between water temperature and stream flow while the R-squared value provides an indication of the deviation of data from the line of best fit. Together, the trendline slope and R-squared values aid in characterizing the correlation between the two variables for a given dataset.

The results of these statistical analyses indicate that stream flow and water temperature do not have a strong correlation when isolated from other factors that affect stream temperatures in a natural setting (based on the low absolute value of the slopes and the very low R-squared values).

As noted earlier, the literature search indicated that air temperature is a much stronger predictor of water temperature. Figure 4.6.2-11 shows this relationship and notes the statistical results. The absolute value of the slopes and the R-squared values are significantly greater for these parameters, indicating a much stronger relationship.

Figure 4.6.2-11
Air Temperature Versus Water Temperature for Section 303(d) Listed Stream Segments in the Fraser River Basin

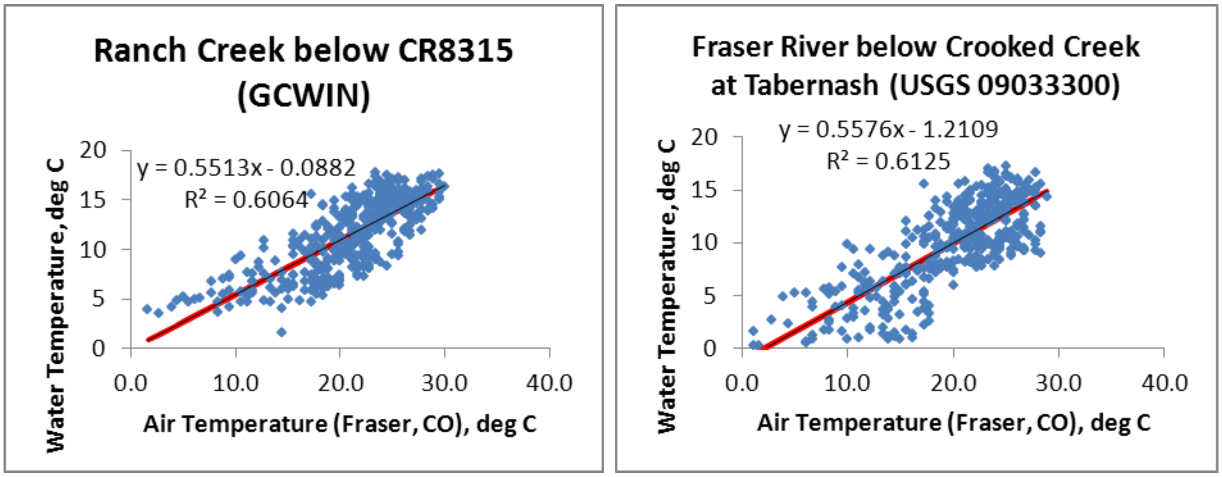
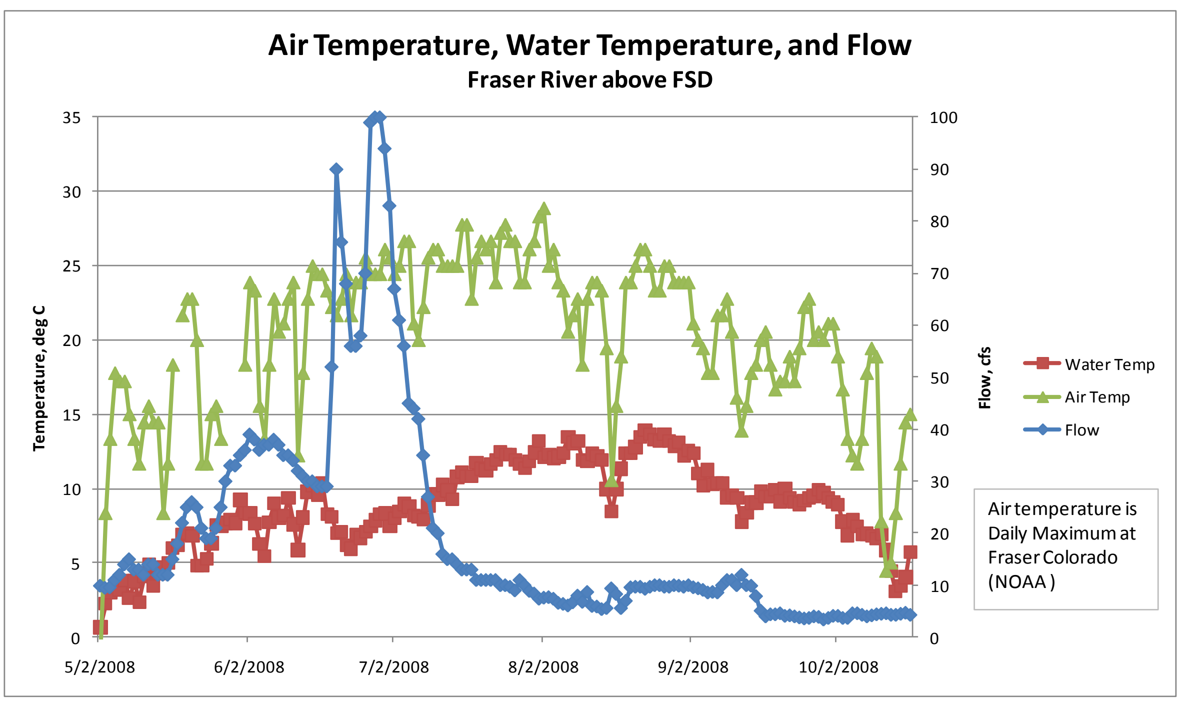


Figure 4.6.2-12 shows the relationship between historic air temperature, water temperature, and flow from May to October of a typical year on the Fraser River.

Figure 4.6.2-12
Typical Water Temperature, Air Temperature, and Flow Over Time



Peak temperatures (both air and water) lag behind the peak of the runoff by two weeks to a month. In general, air and water temperatures track together, with maximums and minimums occurring at nearly the same time. Generally, flow reductions attributable to the Proposed Action with RFFAs would occur during peak flow periods, before air temperatures reach maximum levels for the summer. By the time maximum seasonal water and air temperatures occur, projected flows under the Proposed Action with RFFAs would be very similar to flows under Current Conditions (2006).

The third phase of the statistical analysis involved additional analysis of the three stream reaches with previous exceedances of stream temperature standards (two reaches of the Fraser River and one reach of Ranch Creek that are on the Section 303[d] List) to determine whether statistical relationships between stream temperature and stream flow are improved by isolating the analyses for narrow bands of air temperature.

According to the literature search noted above, the top four variables that influence water temperature were considered for evaluation and are listed below in order of importance:

1. Air temperature
2. Percent shade
3. Relative humidity
4. Flow

Of these four variables, two (shade and flow) can be human-influenced. Shading can be greatly affected by human activity through the destruction of riparian vegetation (through, for example, grazing, recreational activities and vegetative clearing) or through habitat restoration programs. To determine the potential effect of flow changes caused by the Proposed Action with RFFAs, percent shade was considered constant. Additional analysis was undertaken to evaluate the water temperature-flow relation for isolated air temperatures or narrow bands of temperature ranges. To accomplish this analysis, an additional station upstream on the Fraser River was used to augment data for evaluation. In total, three locations were selected based on the data availability. The data sources were as follows:

- GCWIN station with data logger for temperature that provided a minimum of one-hour readings or USGS station with daily temperature readings
- Weather station with maximum daily air temperature
- USGS stream flow gages

The stations used at each location are as follows:

- Fraser River Near Winter Park (Period of Record: 2007-2010)
  - GCWIN Station: FR-blwWP – 15-minute increment water temperature
  - USGS Station: #09024000 (Fraser River at Winter Park) – daily flow
  - National Oceanic and Atmospheric Administration (NOAA) Weather Station: #53116 (Fraser) – maximum daily air temperature

- Fraser River Near Tabernash (Period of Record: 2006-2010)
  - GCWIN Station: FR-blwCr – 30-minute increment water temperature for 2006
  - USGS Station: #09033300 (Fraser River below Crooked Creek) – daily flow for period of record and average daily temperature for 2007 to 2010
  - NOAA Weather Station: #53116 (Fraser) – maximum daily air temperature
- Ranch Creek (Period of Record: 2007-2010)
  - GCWIN Station: RC-blwCR8315 – 15-minute increment water temperature
  - USGS Station: #09032000 (Ranch Creek nr Fraser) – daily flow
  - NOAA Weather Station: #53116 (Fraser) – maximum daily air temperature

The start of the period of analysis for each location began the first year that GCWIN or USGS took daily (or more frequent) temperature readings. The end of the period of analysis is 2010. Only data from July and August were evaluated as this is the time of year of when exceedances of the State water temperature standard typically occur. In many years, data collection for stream temperature did not begin until between late June or mid-July.

The data are presented in the units in which the data are collected in the field measurements and databases. The water temperature data have units of degrees Celsius; the air temperature data have units of degrees Fahrenheit (°F); and the flow data have units of cubic feet per second (cfs). The flow and water temperature data were sorted and grouped according to air temperature. When sufficient data points were available, the data were then plotted for a single air temperature. When the number of data points were sparse (e.g., at the high and low ends of the air temperature range), the data were grouped and plotted for a range of air temperatures to provide sufficient points to develop lines of best fit.

This analysis focused on the potential correlation of low flow with stream water temperature. To isolate and assess this correlation, snowmelt runoff-related data points were excluded from the datasets. Data points corresponding to snowmelt runoff were identified as flows above the 85th percentile. This allowed the analysis to focus on the lower flow rates when exceedance of the State standard of water temperature is more likely to occur. Additionally, to confirm that the excluded data points were snowmelt runoff-related, the dates corresponding to these data points were analyzed. For the Fraser River near Tabernash and Colorado River sites, all excluded data occurred prior to July 15th. For the Ranch Creek site, over 90% of the data excluded occurred before July 15th. For these three sites, it was determined that data points above the 85th percentile of flow are likely data during runoff periods. For the Fraser River near Winter Park site, about 50% of the data excluded occurred before July 15th.

Water temperature data was used as presented by either GCWIN or USGS. The method and equipment used for data collection was not fully identified in the available information sources. Localized stream temperatures can be strongly influenced by shading, depth of water, and movement of water (pooled area versus in the middle of the channel). Accuracy can also be impacted by the equipment and whether or not equipment has been appropriately calibrated. Data from GCWIN was reported to the thousandth of a degree. Accuracy was not known but was likely to have been within a tenth of degree or less, particularly between years. USGS water temperature data was reported to a tenth of a degree. Again, accuracy was not known but was likely to have been within a tenth of a degree or less, particularly between years.

The degree of correlation between the two variables, stream temperature and stream flow, was then determined for all three stations. Evaluation for all three stations is discussed below.

Fraser River Near Winter Park. Graphs illustrating the relationship between maximum daily air temperature and maximum daily water temperature are presented in Figure 4.6.2-13.

No water temperature exceedances were observed in the data analyzed for this site. Flows evaluated in July and August in this analysis had a minimum of 5.4 cfs and an 85th percentile of 18.15 cfs. Trend line slopes for these air temperature groups range between -0.46 to +0.18. The average slope of all the trend lines is -0.19, indicating that potential trends identified in this data could be at least partially due to the measurement error for water temperature data. Additionally, the trend lines are not consistent, as shown with the 77°F air temperature grouping indicating an increase in water temperature with increased flow. The R-squared values ranged from 0.02 to 0.39. Eight of the 11 R-squared values were below 0.2, indicating strong deviation in the data from the line of best fit. The air temperature group with the strongest data fit was the 71-72°F group with an R-squared of 0.39. The slope of the line of best fit for this group was -0.24, indicating a predicted change in water temperature that is likely near or within the error of measurement in the data. At the highest air temperatures 81-84°F, the R-squared value is very low, 0.02 and the slope of the best fit line is also very low, 0.07, indicating essentially no correlation between water temperature and stream flow on the hottest days. Although some of the trend lines indicate a weak negative correlation between water temperature and stream flow, this correlation is not well supported by the data. This analysis indicates that, for these datasets, stream flow, when evaluated in isolation from other factors known to affect water temperature, cannot be reliably used as a predictor of water temperature at this site.

An additional sensitivity analysis was also performed using the entire dataset (including data at times when stream flows were above the 85th percentile). The temperature group with the highest R-squared value was evaluated with the inclusion of all data. The line of best fit for all data for the 71-72°F grouping showed significantly lower correlation between water temperature and stream flow, although the deviation of data from the line of best fit was somewhat less. In addition, the temperature group with the lowest correlation, the 79°F group, was evaluated with the inclusion of all non-runoff data. Again, the line of best fit showed lower correlation between water temperature and stream flow with about the same deviation of data from the line of best fit. It was determined that removing the highest flow data does not appear to significantly affect the evaluation aimed to correlate water temperature and stream flow for post-snowmelt runoff flows.

Figure 4.6.2-13
Mean Daily Flow Rate Versus Water Temperature for Fraser River Near Winter Park (No Exceedance of State Water Temperature Standard at this Site)

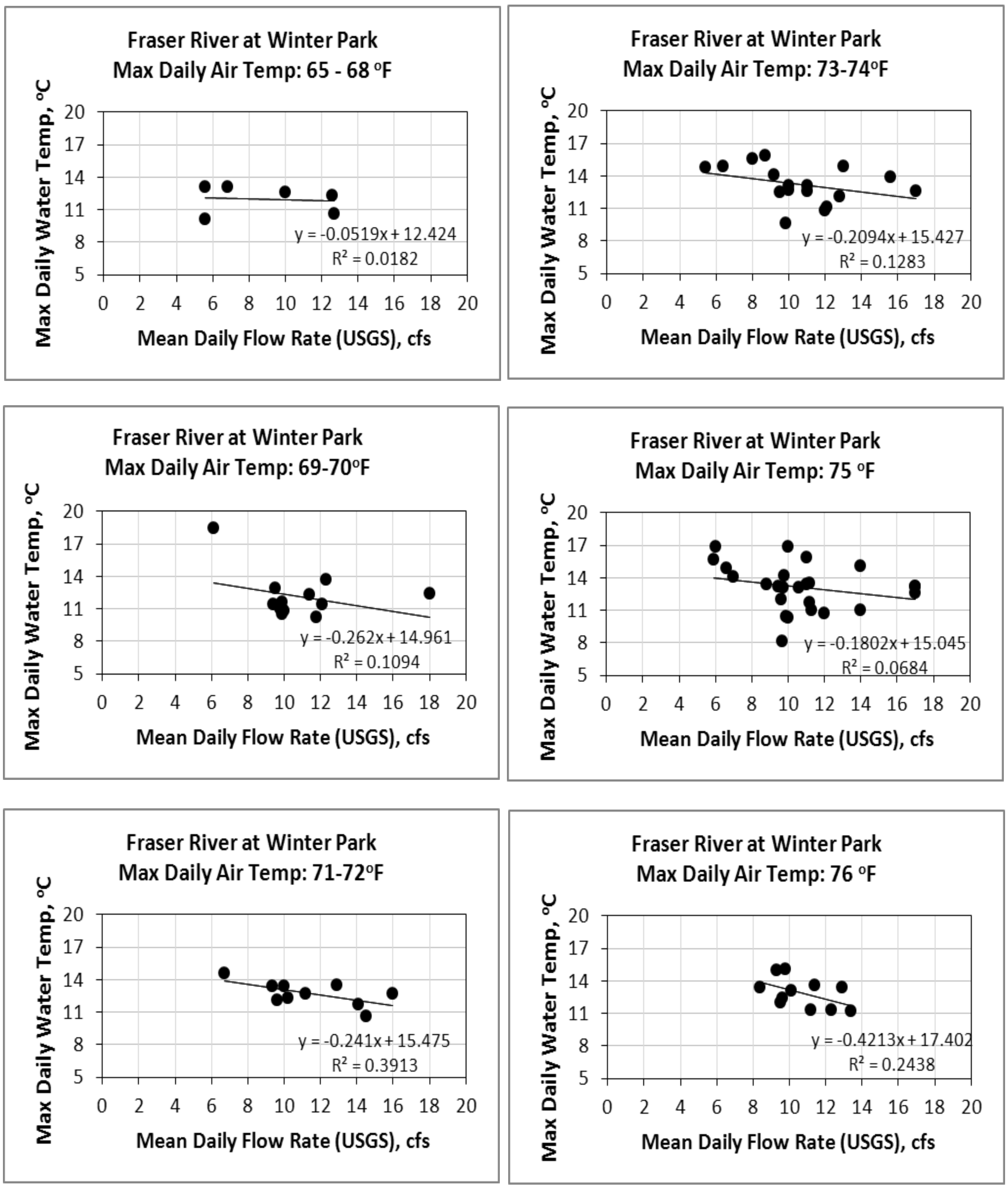
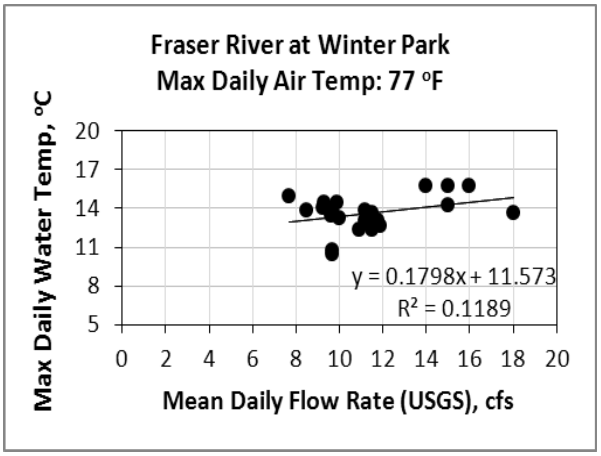
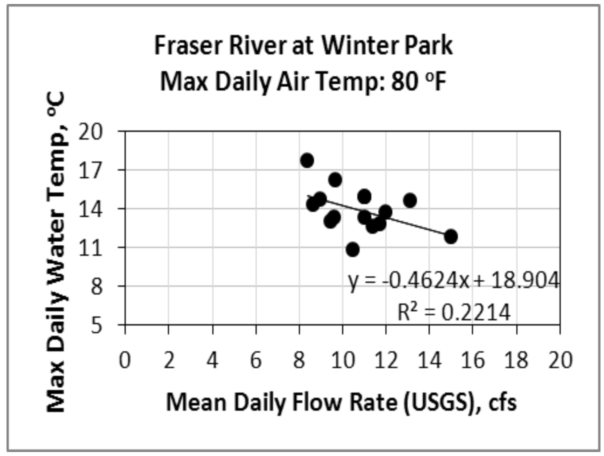
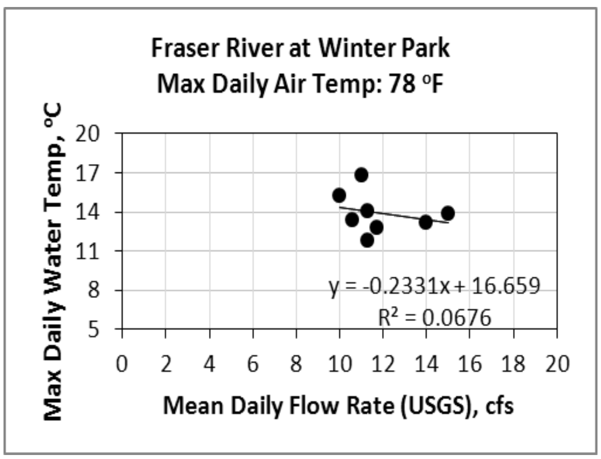
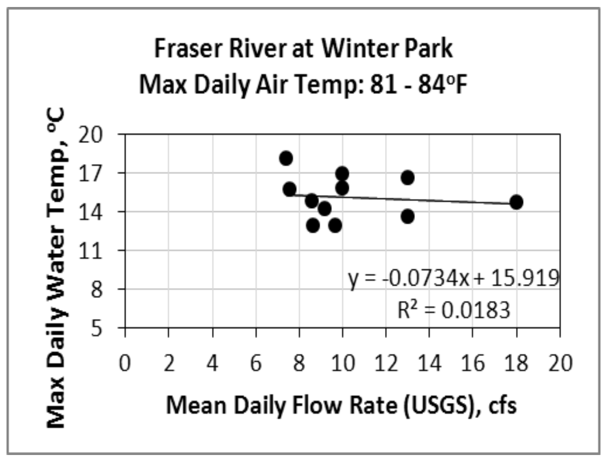


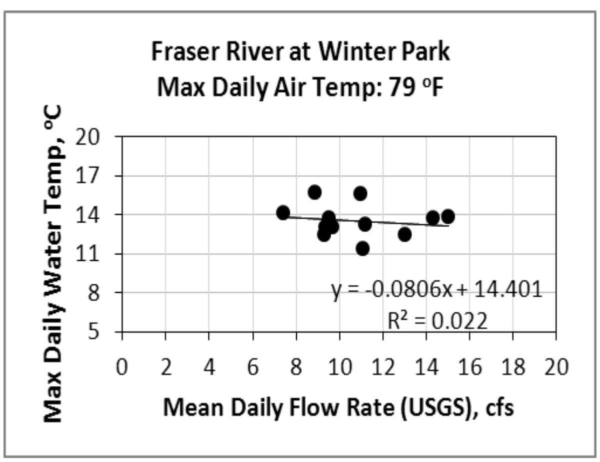
Figure 4.6.2-13 (continued)
Mean Daily Flow Rate Versus Water Temperature for Fraser River Near Winter Park (No Exceedance of State Water Temperature Standard at this Site)











Fraser River below Crooked Creek. Figure 4.6.2-14 includes a series of graphs charting flow rate versus water temperature for the Fraser River near Tabernash. This site has not exceeded the State water temperature standard in any data evaluated. The minimum flow for July and August in the data evaluated was 40 cfs, and the 85th percentile flow was 201 cfs. The range of slopes for the air temperature groups is -0.05 to +0.01, with three temperature groups indicating an increase in water temperature with an increase in flow. The average slope for the lines of best fit was -0.01, or about 0.1 degree change in water temperature for every 10 cfs change in flow. R-squared values ranged from 0.0001 to 0.62, with nine of twelve air temperature groups having an R-squared less than 0.2, indicating high deviation between the data and the line of best fit for most temperature groups. The three air temperature groups with an R-squared greater than 0.2 occurred for air temperatures at or above 77°F. The steepest slope was -0.0534, or about 0.5 degrees for every 10 cfs increase in flow in the highest air temperature group (82 to 85°F). This line of best fit had an R-squared of 0.62, indicating some deviation of the data from the line of best fit. Therefore, the highest air temperature days showed the strongest correlation between water temperature and stream flow. The other two air temperature groups with R-squared values over 0.2, 77, and 78°F, have negative slopes of 0.02 or less, indicating little correlation between water temperature and stream flow. Given the inconsistencies in the water temperature-stream flow relationships in the different air temperature groups, and the generally high deviation in the data from the lines of best fit for most air temperature groups, this analysis indicates that, for these datasets, stream flow, when evaluated in isolation from other factors known to affect water temperature, cannot be reliably used as a predictor of water temperature at this site.

Figure 4.6.2-14
Daily Mean Flow Rate Versus Water Temperature for the Fraser River below Crooked Creek (No Exceedance of State Water Temperature Standard at this Site)

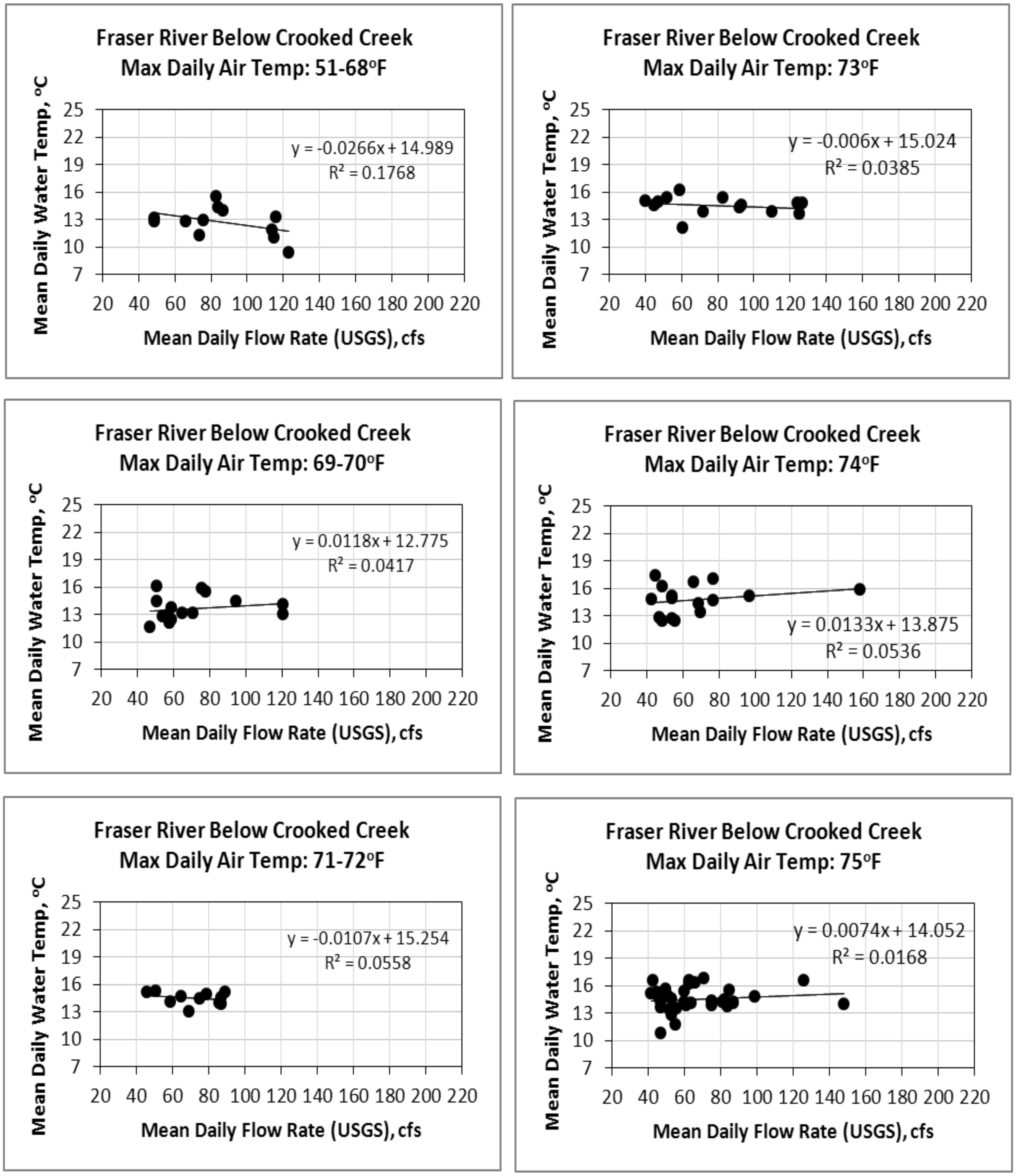
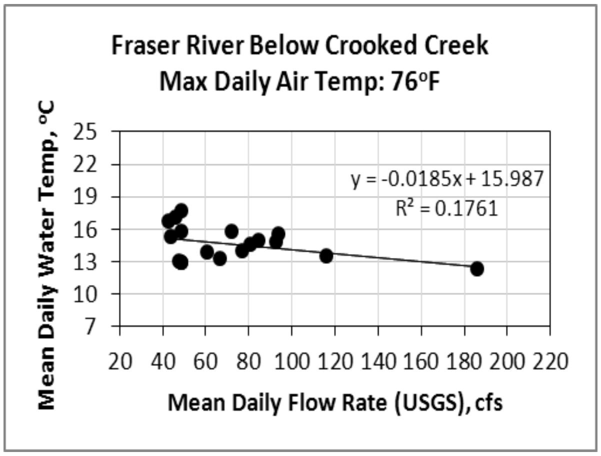
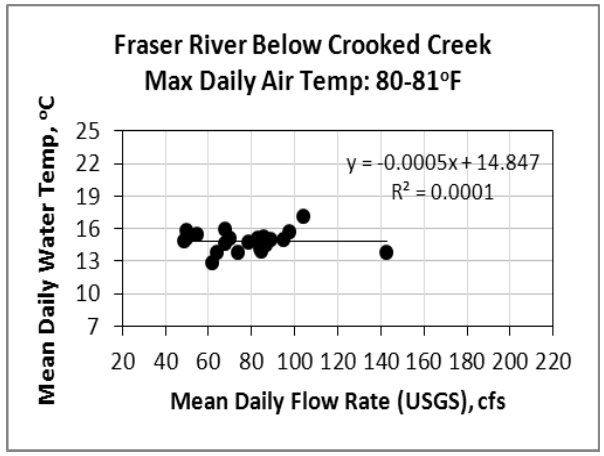
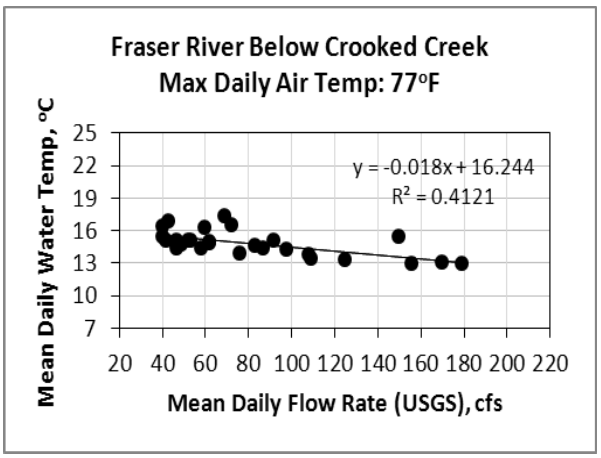
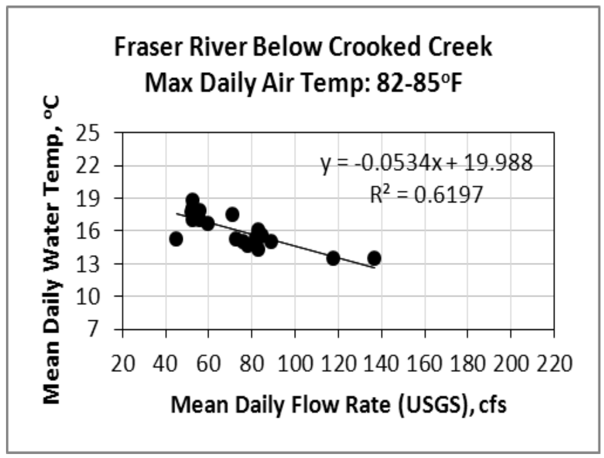


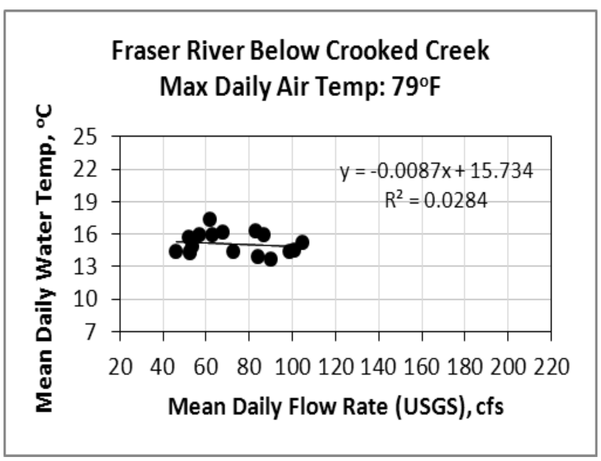
Figure 4.6.2-14 (continued)
Daily Mean Flow Rate Versus Water Temperature for the Fraser River below Crooked Creek (No Exceedance of State Water Temperature Standard at this Site)











Ranch Creek. Figure 4.6.2-15 shows graphs developed to analyze temperature effects for Ranch Creek. As documented in Section 3.2, Ranch Creek has historically experienced numerous exceedances of the State water temperature standard. The minimum flow for July and August in the data evaluated was 2.6 cfs, and the 85th percentile flow was 7.5 cfs. The range of slopes for the temperature groups is -1.9 to +0.5 indicating an inconsistent relationship between water temperature and flow for the different temperature groups. Some air temperature groups had increasing water temperature with increasing flow, while some had decreasing water temperature with decreasing flow. Five air temperature groups had a slope with an absolute value less than 0.2, indicating negligible correlation between water temperature and flow for this dataset. R-squared values ranged from less than 0.00 to 0.30, with all but two less than 0.08. These low R-squared values indicate high deviation in the data from a line of best fit. Therefore, the line of best fit does not appear to represent a relationship between the two variables for all but two air temperature groups.

Two groups, air temperature of 80°F and air temperature from 83 to 86°F, have a higher R-squared value (0.17 and 0.31, respectively). However, the air temperature group between those two (the 81 to 82°F group) had an R-squared of 0.02. Therefore, little correlation between water temperature and stream flow is apparent for this dataset. At the highest air temperature group, the slope of the best fit line is -1.9 with an R-squared of 0.30. Therefore, at the highest air temperatures, a weak negative correlation between water temperature and flow rate is shown. However, given the inconsistencies in the water temperature-stream flow relationships in the different air temperature groups, including the adjacent air temperature group which indicated high deviation in data from the line of best fit, a direct statistical correlation between water temperature and stream flow that can be used in a predictive manner and absent other factors that affect stream temperature is not apparent. Given the R-squared value of only 0.30, an increase in stream flow is not a good predictor of reducing water temperature. For example, the highest water temperature data point did not occur at the lowest flow. Also, the second-lowest water temperature data point occurred at one of the lowest flows. Therefore, the data do not support water temperature decreases to be caused by an increase in flow.

Additional data evaluation was performed to determine the relationship between water temperature and stream flow. The first day of temperature exceedance was evaluated to determine if stream flow increased or decreased from the previous day. For the 29 periods of acute water temperature exceedances (DM), 16 indicated stream flow decreased from the previous day and 13 days indicated stream flow increased or stayed the same. This further supports there being little to no direct statistical relationship between stream flow and water temperature at this site that can be in isolation from other factors known to affect water temperature, to reliably predict water temperature. Additionally, if lower stream flow were correlated with higher water temperature, the number of temperature exceedances would be expected to be concentrated on days with stream flow below the 15th percentile. The total number of data points above the stream standard was 70; of these, 11 occurred on days when the stream flow was below the 15th percentile. Therefore, about 15% of days with stream standard exceedances for water temperature occurred when flow was less than the 15th percentile. Again, this supports a conclusion that the available data do not allow a direct statistical relationship to be used to predict changes in stream temperature solely due to changes in stream flow. This is also supported by the three recent TMDLs for water temperature that are referenced in Section 3.2. These TMDLs used increasing riparian vegetation as the preferred BMP for reducing water temperature, rather than modifications to the flow rates.

Figure 4.6.2-15
Mean Daily Flow Rate Versus Water Temperature for Ranch Creek below CR 8315

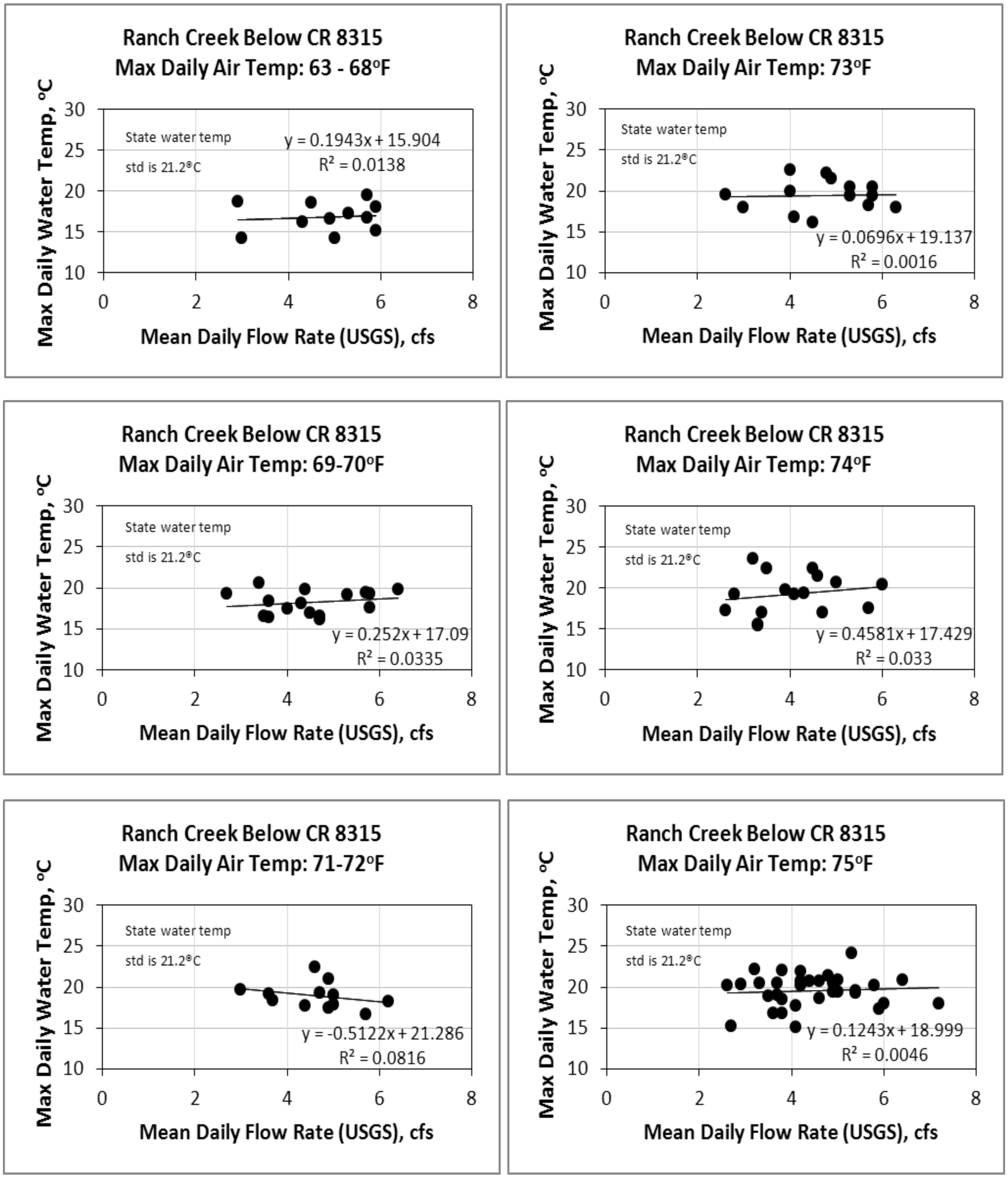
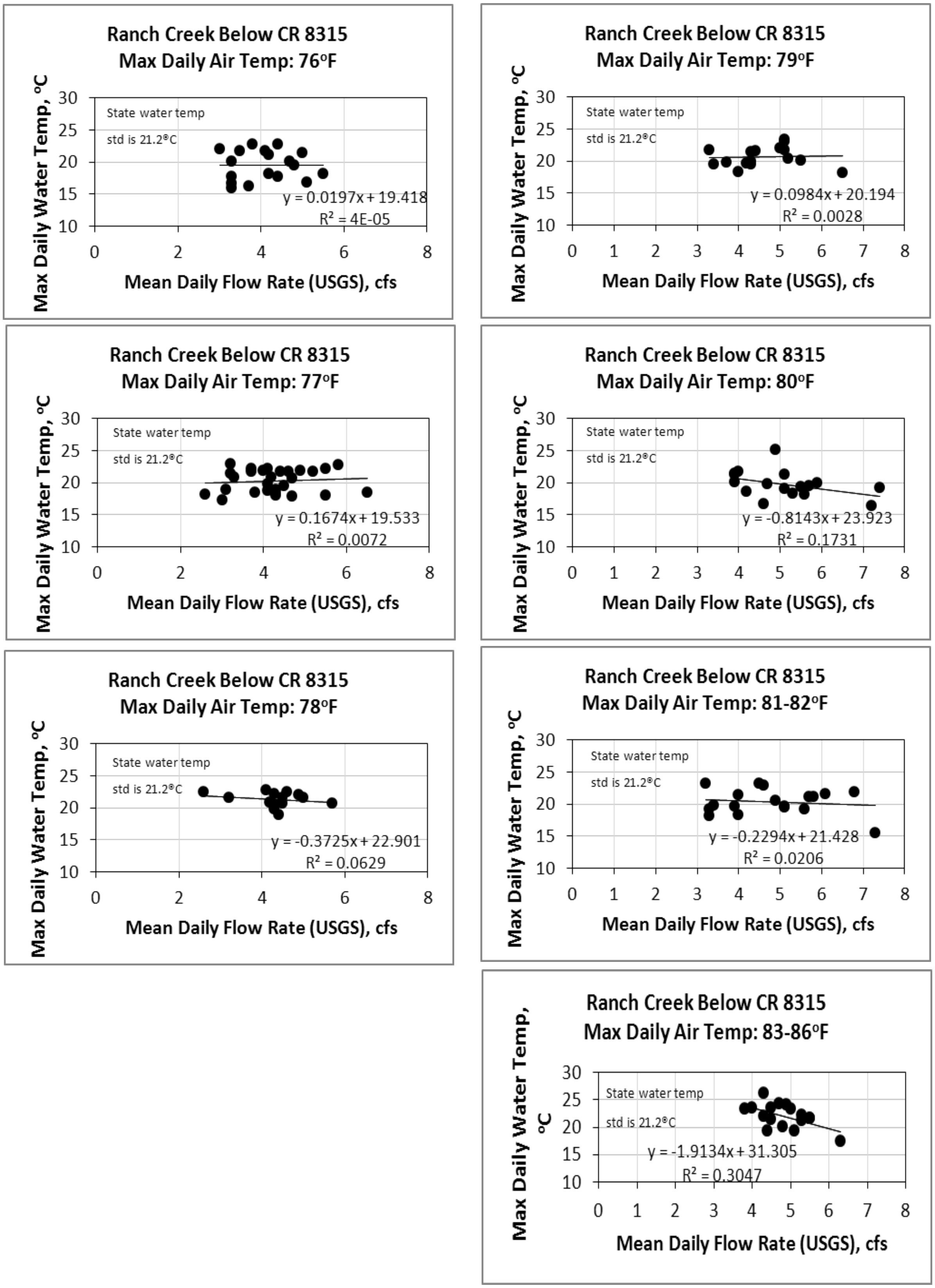


Figure 4.6.2-15 (Continued)
Mean Daily Flow Rate Versus Water Temperature for Ranch Creek below CR 8315



<u>Conclusions Regarding Fraser River Temperature Effects</u>. The data indicate that stream flow, in isolation from other factors that affect stream temperatures, is a poor predictor of water temperature for all three sites. This analysis is supported by low R-squared values and flat slopes on the line of best fit. Based on the historical record of DM and MWAT exceedances in the Fraser River Basin, it is possible that such exceedances could occur in the future during periods when diversions related to the Proposed Action with RFFAs would be taking place. Site-specific conclusions are discussed below:

- **Fraser River Near Winter Park** – The highest air temperature group had an R-squared value of 0.02, and a trendline slope of 0.07 indicating little to no correlation between water temperature and flow rate for this dataset.
- **Fraser River below Crooked Creek** – The highest air temperature group had an R-squared of 0.62 and a slope of -0.05. This indicates a weak correlation between flow and stream temperature. However, the data was inconsistent for other air temperature groups, with some indicating positive correlation (a positive slope) and very low slopes (absolute value of 0.02) at the highest R-squared values.
- **Ranch Creek** – The highest air temperature group had an R-squared of 0.30 and a slope of -1.9. This indicates the potential for a correlation with the slope but the R-squared value is not indicative of a good fit of the line. Additionally, the data was inconsistent for the other air temperature groups, with some indicating positive correlations, and R-squared values varying widely between adjacent air temperature groups. Additional evaluation indicated that high stream temperature days were not clustered on low flow days, providing further evidence of little to no correlation between flow and stream temperature.
- **Fraser River Segments 10b and 10c** – Full Use with a Project Alternative with RFFAs (2032) conditions are not expected to cause more frequent exceedances of the stream temperature standards as a result of changes in flow. Sections 10b and 10c of the Fraser River are already impaired, as evidenced by the Section 303(d) listing. The combination of past actions, flow changes resulting from Full Use of the Existing System, RFFAs, and the Proposed Action would result in a negligible level of impact based on the type of analysis that could be reasonably performed with available data and methods. More frequent occurrences of stream temperatures approaching or exceeding standards are not anticipated under the Proposed Action with RFFAs and the available data cannot be used to reliably predict changes in stream temperature due solely to flow changes during the period of most concern, mid-July to the end of August. It is anticipated that, if data can be obtained to support a multi-variable analysis considering the interplay between all the factors affecting stream temperatures, this analysis may yield impacts up to moderate levels.

c) Permit Compliance for Moffat Railroad Tunnel Discharges

The Moffat Railroad Tunnel Discharge Permit allows for discharge of railroad tunnel seepage water to either the Fraser River or South Boulder Creek under permit number CO-0047554. Discharge to South Boulder Creek is limited to 0.5 million gallons per day (mgd), or about 0.77 cfs. Because this flow is seepage water, the maximum flow is not expected to increase.

The Moffat Railroad Tunnel has a discharge permit for groundwater seepage that includes interim and final limits. The final limits include 30-day average, DM and two-year averages for several parameters. As shown in Section 3.2, the 30-day average and DM for copper and dissolved lead exceed the stream standard. The two-year average, however, is similar to the stream standard. Two potential impacts would occur with a change in flow near this discharge. The first is an impact to the discharger via tighter permit limits. The second is the potential for the Fraser River to exceed stream standards due to reduced dilution water in the stream at the time and point of discharge.

The acute and chronic low flow at PACSM Node 2580 was estimated using the CDPHE modified version of EPA's DFLOW model (Pierce 2010). The estimated acute and chronic low flow for Current Conditions (2006) was determined using PACSM estimated flows. Similarly, PACSM estimated flows were used to determine low flow under Full Use with a Project Alternative with RFFAs (2032). Acute low flow would decrease approximately 28% from 2.8 to 2.0 cfs and the chronic low would decrease approximately 8% from 2.8 to 2.6 cfs. Note that the current permitted discharge from the Moffat Tunnel is 0.5 mgd, or about 0.77 cfs.

There is a potential impact to the Moffat Railroad Tunnel Discharge Permit number CO-0047554 as a result of decreased acute and chronic low flows. The degree of impact to this permit, however, is unknown, as current permit limits provide for some parameters to be discharged at greater than stream standards. It is likely that reduced dilution water during low flow times combined with a maximum flow discharge from the Moffat Railroad Tunnel would cause exceedances of stream standards for some parameters, particularly dissolved zinc.

d) Potential Changes in Nutrient Levels

Monthly concentrations for total nitrogen and total phosphorus along the Fraser River were simulated with a mass-balance loading model for Current Conditions and Full Use with the Project with RFFAs (2032). The model simulates the reach of the Fraser River from Winter Park (above the Winter Park WWTP) to the mouth. Flows and nutrient loads enter along the simulated reach within the model and concentrations are calculated. Natural attenuation processes (loss mechanisms for nutrients, including settling, uptake, and denitrification) are accounted for through application of attenuation coefficients set during model calibration.

Nutrient sources in the model include:

- On-site wastewater treatment systems (OWTSs),
- Six WWTPs (Winter Park, Fraser, Tabernash, Devil's Thumb, Young Life, and Granby WWTPs), and
- Land use loading.

Nutrient loading from OWTSs was estimated based on an estimated population using septic and literature values estimating transmission of nutrients through septic tanks and into surface water. Of the 4,600 people living in the Fraser River Basin (Grand County 2001), an estimated 30% use OWTSs, resulting in an estimate of 1,380 people on septic systems. Lowe et al. (2009) estimate 171 liters of water per person per day entering the septic tank. Colorado median values for concentrations exiting the septic tank from Lowe et al. (2009)

were also applied (71 mg/L for total nitrogen and 11.4 mg/L for total phosphorus). To estimate the mass transmitted to surface water after exiting the tank, estimated percent transmittal rates from EPA (2002) were applied (85% of total nitrogen and 10% of total phosphorus). Applying these values produced estimates of 5,198 kilograms per year (kg/yr) TN and 98 kg/yr of total phosphorus reaching surface water from OWTSs in the Fraser River Basin. In the model, the annual load from OWTSs applied to each sub-basin was distributed monthly in proportion with the percent of annual flow in the river for the given month. Given the uncertainty in these estimates, a range of OWTS loading rates were tested in the model (up to tripling the noted estimates in the absence of any attenuation), and prediction of Fraser River concentrations was found to not be very sensitive to this loading term, since it is small relative to the other terms.

Loading from WWTPs was estimated on a monthly basis applying estimated current and projected (2032) concentrations and flow rates. Data from the year 2012 were used to establish Current Conditions (2006) for this analysis because 2012 was the first year WWTP's began reporting effluent total nitrogen values. Concentration assumptions, presented in Table 4.6.2-7, were developed considering historical nutrient discharges, characterization of site-specific wastewater treatment processes, and determination of expected WWTPs performance based on correlation with published typical values for the site-specific treatment processes (AECOM 2013).

Table 4.6.2-7
Assumed WWTP Effluent Concentrations for Total Nitrogen and Total Phosphorus, Current Conditions (2006) and 2032

WWTP	Current Conditions (2006)		2032	
	TN (mg/L)	TP (mg/L)	TN (mg/L)	TP (mg/L)
Young Life	34.0	5.0	34.0	5.0
Devil's Thumb Ranch	20.0	5.0	20.0	5.0
Granby	8.4	5.0	8.4	1.0
Tabernash	6.7	5.0	16.5	5.0
Fraser	20.0	5.0	18.0	1.0
Winter Park	17.4 / 39.9[1]	5.0	40.0	5.0

Notes:
[1]For Current Conditions, Winter Park TN concentrations are estimated to be 39.9 mg/L from December through April, and 17.4 mg/L from May through November, based on observed seasonal patterns that matched expected summer versus winter performance.
mg/L = milligrams per liter
TN = total nitrogen
TP = total phosphorus
WWTP = Wastewater Treatment Plant

The methodology applied to develop these total phosphorus and total nitrogen concentrations is described below (as developed by AECOM 2013).

Total Phosphorus – Based on review of the available data, site-specific treatment process, and typical WWTP influent/effluent values, the following methodology was developed:

- Without site specific total phosphorus performance data, considering the treatment process at each facility, typical values for WWTP secondary treated effluent are recommended (range of 4-5 mg/L average effluent total phosphorus).
- Use of 5 mg/L average total phosphorus is recommended for all facilities in the 2012 model year runs.
- Use of 1 mg/L average total phosphorus is recommended for Granby and upper Fraser Valley in the 2032 model year runs based on Regulation #85 effluent limit requirements that will apply at that time.

Total Nitrogen – Based on review of the available data, site-specific treatment process, and typical WWTP influent/effluent values, the following methodology was developed:

- Where effluent total inorganic nitrogen (TIN) values have not been reported and *are not* available, typical treatment performance for the treatment process employed at that facility was used to determine recommended total nitrogen values (applies to Young Life Crooked Creek Ranch and Devil's Thumb Ranch Facilities).
- Where effluent TIN values have been reported and *are* available, the following methodology was used to determine recommended total nitrogen values:
  - Where available effluent data indicates the facility is performing within the range of typical performance for the specific treatment process employed, the available TIN data were used to determine recommended total nitrogen values by adjusting average TIN values to equivalent total nitrogen values as noted in Table 4.6.2-7 (applies to Granby, Tabernash, and Winter Park WWTPs).
  - Where available effluent data indicates the facility is performing below the range of typical performance for the specific treatment process employed, the recommended total nitrogen values were determined based on the typical performance range for the treatment process employed (applies to upper Fraser Valley WWTPs).
- Where the available effluent data indicates there is seasonal variation in the nitrogen removal performance of the facility, "winter" and "summer" average total nitrogen values were developed from the effluent data seasonal trend and applied to the appropriate winter and summer months (applies to Winter Park WWTP).
- Use of the same total nitrogen values for 2012 and 2032 model runs is recommended for all plants except upper Fraser Valley, Tabernash, and Winter Park.
  - Upper Fraser Valley: Use of 18 mg/L average total nitrogen for upper Fraser Valley WWTP in the 2032 model year runs is recommended based on Regulation #85 effluent limit requirements that would apply at that time.
  - Tabernash: Use of 16.5 mg/L average total nitrogen for Tabernash WWTP in the 2032 model year runs is recommended because it is expected that the current nitrogen removal performance may not be sustainable in the future. The current performance is likely tied to very low plant flow rates relative to the facility's permitted capacity, resulting in higher detention times during the process steps that promote denitrification. Therefore, it is expected that higher plant flow rates associated with 2032 conditions would lead to a reduced ability to achieve

denitrification. In addition, the exemption of this facility from CDPHE Regulation #85 requirements reduces the likelihood that this plant would make nitrogen removal performance improvements.

– Winter Park: Use of 40 mg/L average total nitrogen for Winter Park WWTP in the 2032 model year runs is recommended due to anticipated population growth and associated increases in plant flow rates. At higher plant flow rates (greater than 0.2 mgd), the data indicate the facility loses its ability to remove nitrogen. Therefore, it is expected that higher plant flow rates associated with 2032 conditions would lead to a reduced ability to achieve denitrification. In addition, the exemption of this facility from CDPHE Regulation #85 requirements reduces the likelihood that this plant would make nitrogen removal performance improvements.

Model inputs applied PACSM monthly flows. However, to respond to CDPHE comments on the Preliminary Final EIS (CDPHE 2012d), an adjustment was made in WWTP loading for 2032. Specifically, CDPHE expressed concerns that 2032 PACSM WWTP flows were overestimated, resulting in overestimation of WWTP loading in the Fraser nutrient modeling. New flow estimates were developed using Colorado Department of Local Affairs (DOLA) data (https://dola.colorado.gov/ddb/dashboard.jsf?county=49, accessed on August 13, 2013). Monthly flow rates for Current Conditions and the 2032 DOLA-based flows for each WWTP are presented in Table 4.6.2-8.

Table 4.6.2-8
Assumed Monthly WWTP Flow Rates for Current Conditions (2006) and 2032

Months	Devil's Thumb		Fraser Sanitation District		Granby		Tabernash		Winter Park Water & Sanitation District		Young Life/ Crooked Creek	
	Current Con-ditions (2006) (mgd)	2032 (mgd)	Current Con-ditions (2006) (mgd)	2032 (mgd)	Current Con-ditions (2006) (mgd)	2032 (mgd)	Current Con-ditions (2006) (mgd)	2032 (mgd)	Current Con-ditions (2006) (mgd)	2032 (mgd)	Current Con-ditions (2006) (mgd)	2032 (mgd)
January	0.008	0.012	1.068	1.764	0.254	0.419	0.041	0.068	0.125	0.206	0.005	0.008
February	0.007	0.012	1.021	1.686	0.278	0.459	0.040	0.067	0.164	0.271	0.005	0.009
March	0.009	0.015	1.359	2.244	0.254	0.419	0.059	0.098	0.184	0.304	0.006	0.009
April	0.021	0.034	1.164	1.922	0.182	0.301	0.055	0.091	0.125	0.206	0.006	0.011
May	0.052	0.085	0.779	1.286	0.184	0.304	0.038	0.063	0.063	0.104	0.009	0.016
June	0.053	0.087	0.726	1.199	0.291	0.481	0.032	0.053	0.117	0.193	0.018	0.029
July	0.098	0.161	1.157	1.911	0.371	0.613	0.032	0.054	0.125	0.206	0.019	0.031
August	0.076	0.125	1.068	1.764	0.314	0.519	0.024	0.040	0.124	0.205	0.012	0.019
September	0.013	0.022	0.859	1.418	0.299	0.494	0.021	0.034	0.117	0.193	0.006	0.010
October	0.009	0.015	0.930	1.536	0.309	0.510	0.024	0.039	0.125	0.206	0.006	0.009
November	0.008	0.013	1.024	1.691	0.246	0.406	0.030	0.050	0.121	0.200	0.005	0.008
December	0.007	0.012	1.177	1.944	0.306	0.505	0.033	0.055	0.125	0.206	0.004	0.006

Note:
mgd = million gallons per day

Because of concerns about potential inconsistences in analysis that could occur with re-running PACSM with different WWTP assumptions, a solution within the Fraser nutrient model was developed. Because the model is load-based, the reductions in WWTP flow volumes were simulated by adjusting effluent nutrient concentrations from the WWTPs in the 2032 simulations to achieve the target effective loads without changing the flow rates. The inherent assumption behind this approach is that the volume of water in the river is correctly represented by the PACSM results, regardless of the source of that water at the given location (i.e., runoff versus WWTP effluent). Any error related to this assumption would likely be an underestimation of the flow rates in the river should the WWTP flow rates actually be lower than those simulated by PACSM (due to reduced consumption, primarily associated with outdoor use). As such, any error associated with this method is expected to be small but would be expected to produce conservatively higher estimates of concentrations at times in the river in the 2032 simulations.

In addition to OWTS and WWTP loading, nutrients were simulated to enter the model by land-use load. Land-use loading is nutrient loading from the watershed to the river that is not attributable to OWTSs or points sources, such as WWTPs. Land-use loading varies by land-use type. For this modeling effort, land-use types were compiled by sub-basin to support sub-basin-specific land-use loading estimates. The Geographic Information System (GIS) coverages of land use were obtained from Grand County (Grand County 2001). Percent coverages by land use for the 10 sub-basins assessed are presented in Table 4.6.2-9.

Table 4.6.2-9
Land Use by Sub-Basin

Sub-Basin (Alphabetical)	Residential	Commercial	Utilities	Mixed/ Other Urban	Agriculture	Forested	Open Water	Wetland	Tundra/ Bare Ground
Crooked Creek	0.9%	0.1%	0.1%	5.2%	19.1%	73.9%	N/A	0.4%	0.4%
Lower Fraser Direct (from Ranch Creek to the Mouth)	1.0%	1.3%	0.3%	2.5%	34.8%	56.4%	N/A	3.6%	<0.1%
Lower Ranch Creek	0.4%	N/A	N/A	0.4%	7.1%	83.7%	0.4%	0.9%	7.2%
Middle Fraser Direct (from Winter Park to Ranch Creek)	1.1%	0.2%	N/A	5.9%	17.4%	74.1%	0.3%	0.7%	0.2%
St. Louis Creek	<0.1%	0.1%	N/A	0.2%	1.0%	78.7%	N/A	N/A	19.9%
Strawberry Creek	N/A	N/A	N/A	N/A	10.3%	89.7%	N/A	N/A	<0.1%
Ten Mile Creek	0.9%	0.4%	N/A	1.6%	44.6%	52.2%	0.2%	0.1%	<0.1%
Upper Fraser (above Winter Park)	0.1%	0.8%	0.05%	5.8%	4.6%	63.4%	N/A	N/A	25.3%
Upper Ranch Creek	N/A	N/A	N/A	N/A	0.6%	75.1%	0.1%	N/A	24.1%
Vasquez Creek	0.8%	0.0%	N/A	1.6%	2.4%	62.4%	N/A	N/A	32.8%

Note:
N/A = not applicable

Export coefficients were used to predict average annual land-use loads of total nitrogen and total phosphorus for each sub-basin, based on data from Corbitt (1990) and Reckhow and Chapra (1983). Loadings of total nitrogen from wetlands, open water, and tundra/bare ground areas were estimated based on information on atmospheric deposition and precipitation in Colorado (Wolfe et al. 2003). While bare rock and open water connected directly to flowing water might be expected to export most of what is delivered by precipitation, tundra and wetlands would retain much more of these nutrients (Campbell et al. 2000). The land use GIS files do not differentiate between directly-connected and isolated open water or tundra and bare rock. Based on this, 10% of the atmospheric deposition and precipitation estimates were used for export coefficients for these land-use types. Using these assumptions, tundra, open water, and wetlands account for only a small amount of total nitrogen and total phosphorus loading for the basin (less than 2% total). For the other land use types, a wide range of export coefficients are reported in the literature. For this model, export coefficients were set to be the minimum value from Corbitt (1990) and Reckhow and Chapra (1983) for total nitrogen and the minimum plus 10% of the range between the minimum and maximum value for total phosphorus. The rationale for this approach is as follows:

- Because this is not a mechanistic model of nutrient loading, attenuation coefficients are used to calibrate input nutrient loads to match in-river target concentrations based on observed data. Further, since there are no data to support source-specific attenuation settings, attenuation coefficients affect all load sources in a given reach/sub-basin. These attenuation coefficients are locked at calibrated settings for scenario simulations. Given this approach and the uncertainty in export coefficients, it was decided that export coefficients should be set as low as possible to still meet all monthly calibration targets. This effectively minimizes attenuation coefficients while still honoring the literature export coefficients ranges. Minimizing attenuation coefficients was done out of concern that overestimation of actual attenuation could potentially obscure changes in the simulation of scenarios.
- In the case of total nitrogen export coefficients, minimum literature land-use export coefficients, combined with other loading terms (WWTPs and OWTSs), in the absence of attenuation, generated more than sufficient loads to meet calibration target concentrations. For total phosphorus, minimum export coefficients did not generate enough total phosphorus in the system to meet calibration targets in all months. Therefore, minimum export coefficients were increased by 10% of the literature range, so there was more than adequate loading in each month to meet calibration targets.

Table 4.6.2-10 lists the export coefficient data used for the model.

Table 4.6.2-10
Export Coefficients Used in the Fraser Nutrient Model

Land Use	Total Nitrogen (kg/ha/yr)	Total Phosphorus (kg/ha/yr)
Residential	5.00	0.49
Commercial	1.90	0.18
Utilities	1.90	1.22
Mixed/Other Urban	1.90	1.22
Agriculture	1.50	0.58
Forested	1.40	0.10
Open Water	0.20	0.02
Wetland	0.20	0.02
Tundra/Bare Ground	0.20	0.02

Note:
kg/ha/yr = kilograms per hectare per year

As noted, land use loads were divided by sub-basin within the model according to land use breakdown of the basin. Land use loads were also varied by month according to percent of annual flow in the river in the given month. Further, recognizing that load can increase with increased runoff conditions from year-to-year (such as differences reported in Lewis et al. 1984), annual land use loads for scenario runs were adjusted over the 45-year simulation period. The export coefficients applied are rough values in units of mass load per acre per year. In an effort to account for this recognized variation in loading in years with non-average runoff conditions, land-use loads were adjusted by percent multipliers reflecting differences in annual river flow (at the mouth) relative to the average of the 45-year simulation period. The uncertainty of this approach is recognized; however, the available dataset does not support an analysis of sub-basin land use loading over a range of conditions or development of a mechanistic watershed model. This approach was applied consistently over all runs, including simulation of Current Conditions, making results comparable.

Table 4.6.2-11 shows the total annual, unattenuated nutrient loads from the three source types included in the nutrient model for an average year for Current Conditions (2006). The table also shows loading from the WWTPs for 2032, reflecting values in Table 4.6.2-11 and Table 4.6.2-12.

Table 4.6.2-11
Total Average Annual Unattenuated Nutrient Loads to the Fraser River Basin, Current Conditions (2006)

Source-Type	Total Nitrogen Loading (kg/yr)	Total Phosphorus Loading (kg/yr)
Land Use (Current Conditions and 2032)	93,508	13,397
On-site Wastewater Treatment Systems (Current Conditions and 2032)	5,198	98
Six Wastewater Treatment Plants (Current Conditions)	33,171	9,238
Six Wastewater Treatment Plants (2032)	34,053	3,235

Note:
kg/yr = kilograms per year

Table 4.6.2-12
Percent Contribution of Each Loading Term to Simulated Total Nitrogen and Total Phosphorus Concentrations at the Mouth of the Fraser River, Current Conditions (2006)

Source-Type	Total Nitrogen	Total Phosphorus
Upstream Boundary Condition Inflow at Winter Park	0.6%	0.1%
Land Use	52.6%	43.5%
On-site Wastewater Treatment System	3.8%	0.4%
Six Wastewater Treatment Plants	43.0%	56.0%

Table 4.6.2-12 presents the percent contribution of each loading source to the calculated concentration at the mouth of the Fraser River for the calibrated Current Conditions simulation. These percentages were determined by running the model repeatedly (2006)

with only one loading term. Results show that, for this mass balance tool, land use loading and WWTP loading comprise the vast majority of the simulated concentrations response at the mouth of the Fraser River.

As noted above, the model was calibrated by adjusting monthly attenuation factors. For calibration, an average year of input monthly flows was developed from the full set of 45 PACSM years. Monthly inflow concentrations at the upstream end of the model were set to median monthly values for the observed dataset (1995-2012) at USGS gage #09022000, Fraser River at Upper Station near Winter Park. Target monthly calibration total nitrogen and total phosphorus concentrations were developed for five locations in the basin:

- The mouth of Ranch Creek (USGS gage #9033100);
- Fraser River at Tabernash (USGS gage #9027100);
- The mouth of Crooked Creek (USGS gage #395927105505700);
- Fraser River below Crooked Creek (USGS gage #9033300); and
- The mouth of the Fraser River (FR-WGU; Northern Water gage).

Target monthly concentrations at each location were developed from median values using available data collected between 1995 and 2012. Observed minimum and maximum monthly values at each location were also considered in the calibration. Calibration results for total nitrogen and total phosphorus are presented in Figure 4.6.2-16 and Figure 4.6.2-17, respectively.

Figure 4.6.2-16
Total Nitrogen Calibration for Fraser River Nutrient Model

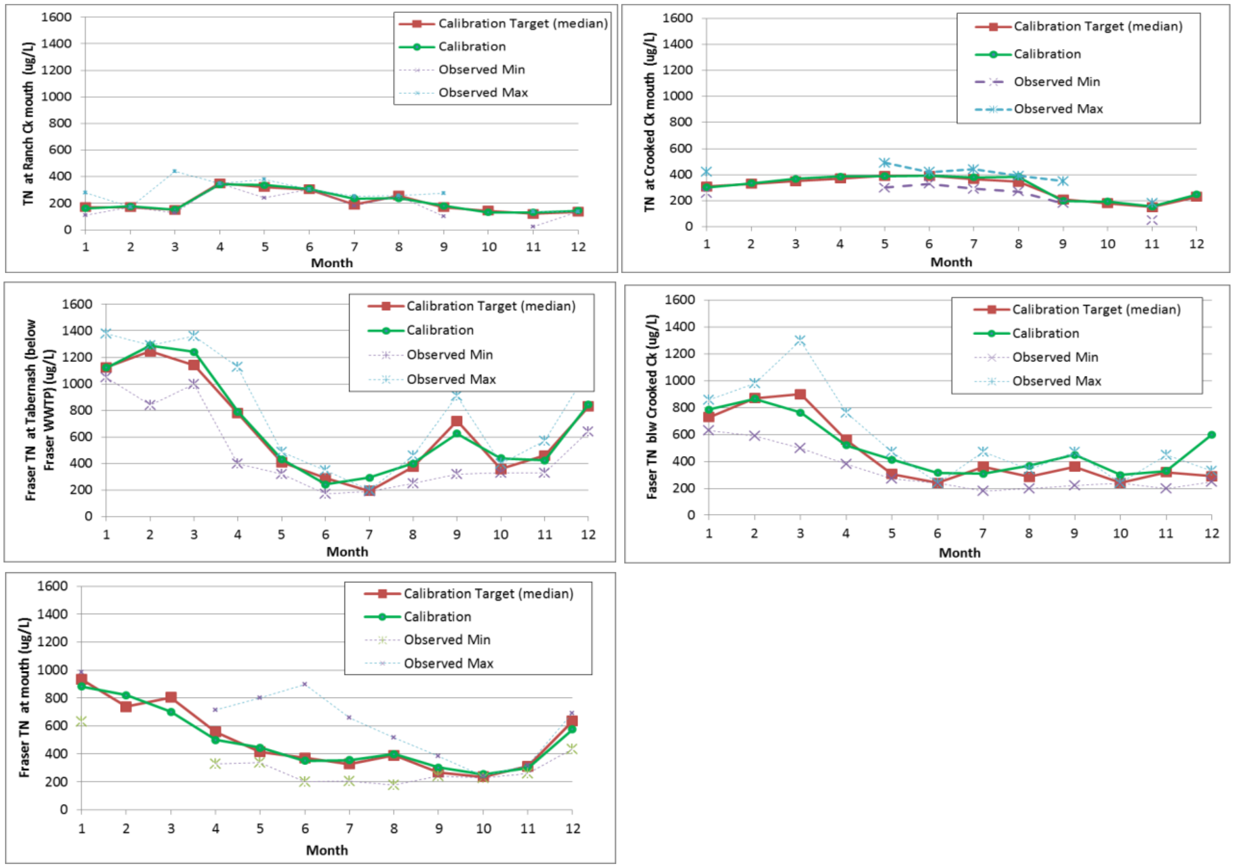
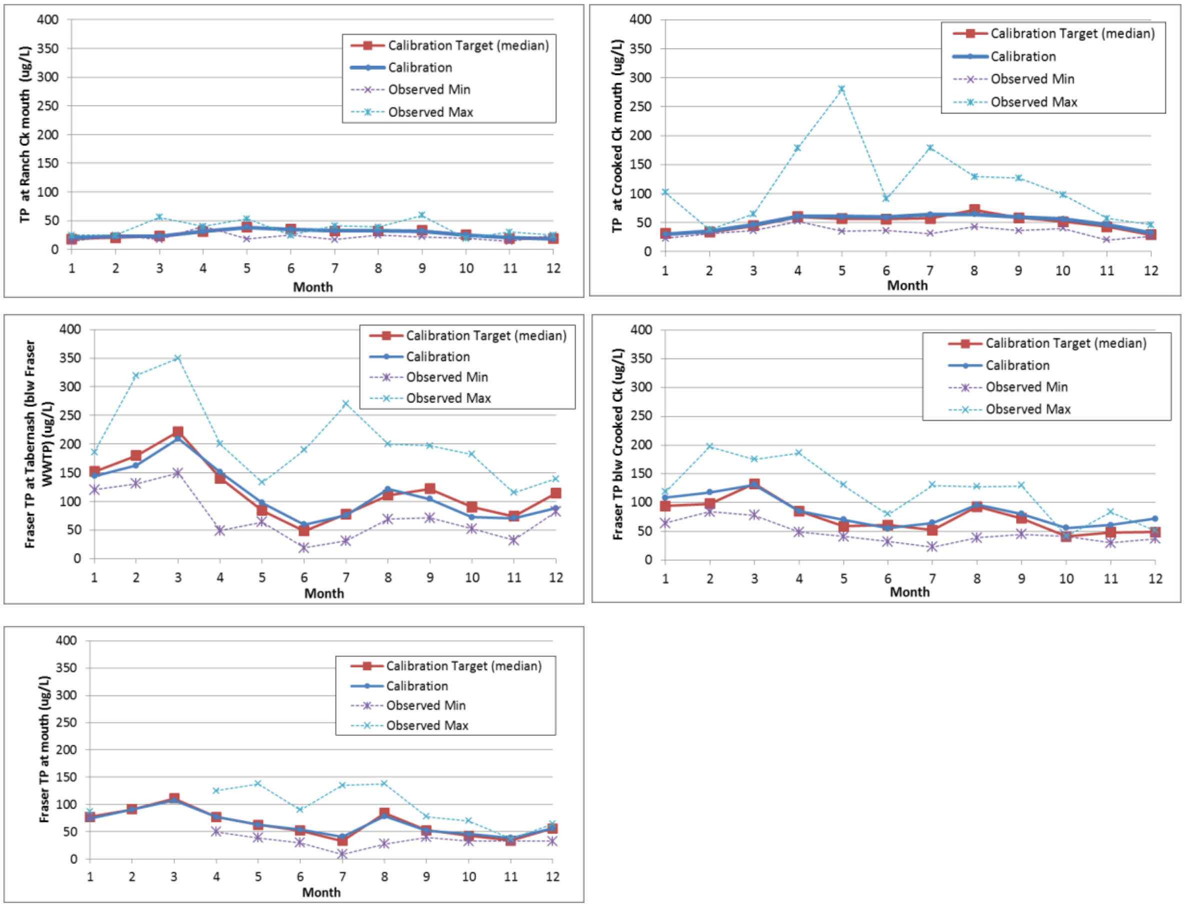


Figure 4.6.2-17
Total Phosphorus Calibration for Fraser River Nutrient Model



The calibrated model was then used to simulate monthly total nitrogen and total phosphorus concentrations along the Fraser River for the PACSM hydrologic period of WY1947 through WY1991. Simulations for 2032 conditions applied identical OWTS loading, assuming all population growth within the Fraser River Basin would use WWTPs. This assumption is consistent with the assumption applied to the hydrologic model (PACSM) simulations. WWTP flows assume 2032 build out for all simulations other than existing use, with flow and concentration assumptions applied as described above. The model provided output from four stations:

- Fraser River below the Fraser Sanitation District WWTP;
- Ranch Creek at the mouth;
- Crooked Creek at the mouth[3]; and
- Fraser River at the mouth.

[3]Denver Water has no diversions or impacts on Crooked Creek but this reach was modeled because permitted discharges in the basin could impact nutrients in the mainstem of the Fraser River.

Results were aggregated into average, dry, and wet years, similar to that done for the PACSM results (refer to Appendix H-2). Time series plots of total nitrogen and total phosphorus concentrations at the mouth of the Fraser River are shown in Figure 4.6.2-18 and Figure 4.6.2-19, comparing simulation results for Current Conditions (2006) and the Proposed Action with RFFAs (2032).

Figure 4.6.2-18
Monthly Simulated Total Nitrogen Concentrations at the Mouth of the Fraser River, Current Conditions (2006) and the Proposed Action with RFFAs (2032)

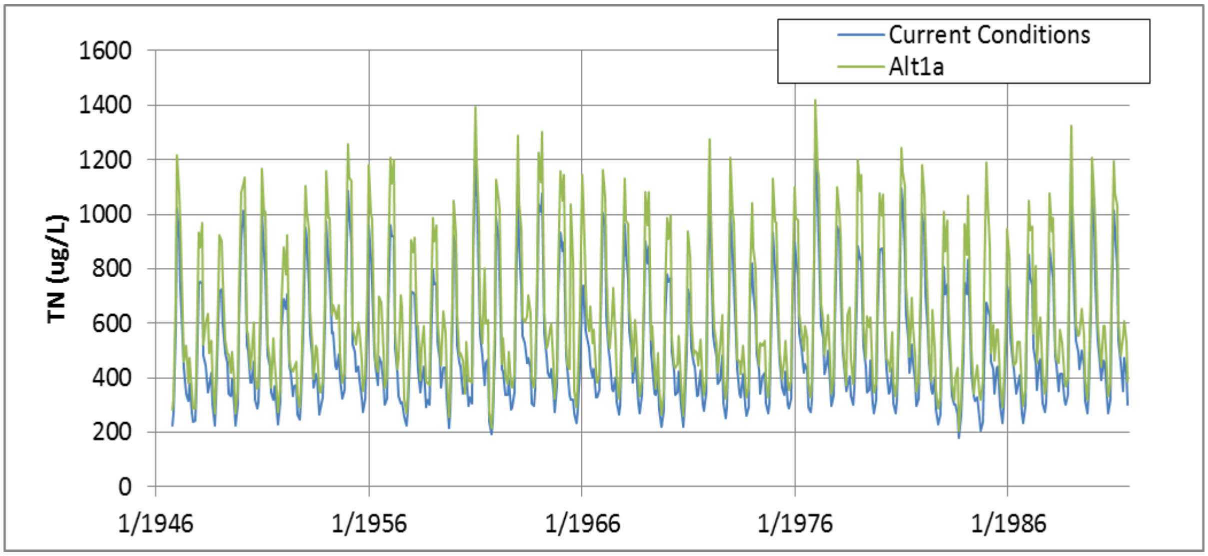
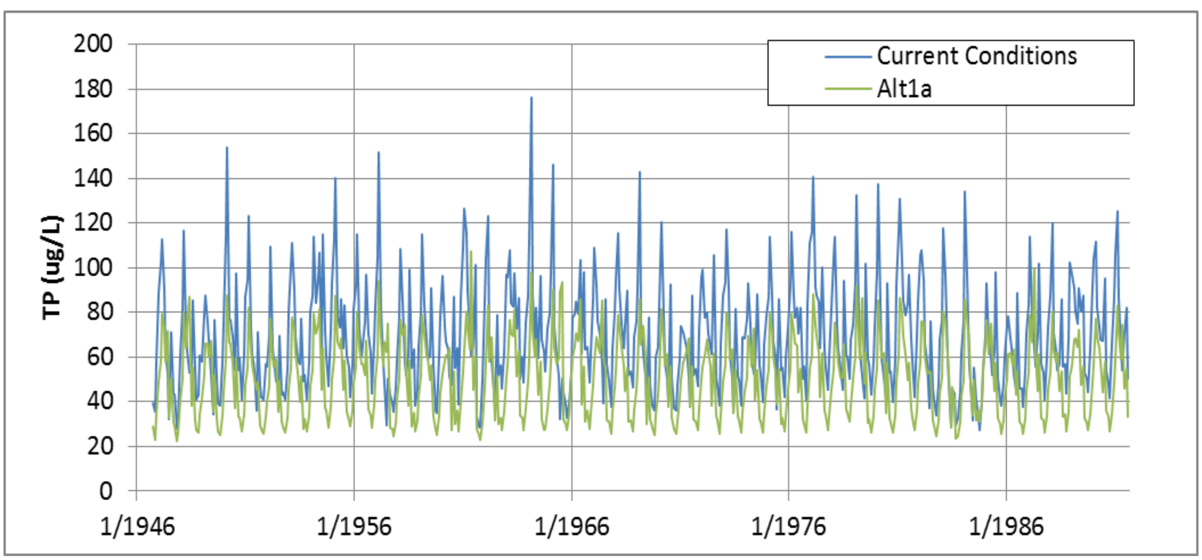


Figure 4.6.2-19
Monthly Simulated Total Phosphorus Concentrations at the Mouth of the Fraser River, Current Conditions (2006) and the Proposed Action with RFFAs (2032)



The results indicate increased total nitrogen concentrations in the Fraser River for the Full Use with a Project Alternative with RFFAs (2032) scenario, and decreased total phosphorus concentrations in the Fraser River for the Full Use with a Project Alternative (2032) scenario, relative to Current Conditions (2006). Simulated total nitrogen and total phosphorus concentrations were similar for all runs simulating 2032 conditions (i.e., Alternatives 1a, 1c, 8a, 10a, and 13a, and the No Action Alternative). The biggest monthly differences in both total nitrogen and total phosphorus concentrations between Current Conditions and 2032 simulations tend to occur in winter months when flow rates are lowest. The differences are largely the result of the simulated changes in loading from WWTPs. As noted in Table 4.6.2-13, annual loads from WWTPs for 2032 simulations increase for total nitrogen, reflecting increased population and flow rates, while WWTP annual loads of total phosphorus decrease (Table 4.6.2-14), due to improved treatment at two major plants discharging to the mainstem (i.e., Granby and Fraser).

Table 4.6.2-13
Modeled Annual Average Total Nitrogen Concentration Changes in the Fraser River Basin

Station	Average Annual Total Nitrogen Concentrations, µg/L		Percent Change
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	
Average Year			
Fraser below Fraser WWTP	742	1,073	+45%
Ranch Creek at Mouth	219	238	+9%
Crooked Creek at Mouth	469	484	+3%
Fraser at Mouth	514	632	+23%
Dry Year			
Fraser below Fraser WWTP	849	1,236	+45%
Ranch Creek	213	228	+7%
Crooked Creek	495	515	+4%
Fraser at Mouth	586	707	+21%
Wet Year			
Fraser below Fraser WWTP	641	926	+44%
Ranch Creek	224	241	+8%
Crooked Creek	390	399	+2%
Fraser at Mouth	461	568	+23%

Notes:
µg/L = micrograms per liter
RFFA = reasonably foreseeable future action
WWTP = Wastewater Treatment Plant

Table 4.6.2-14
Modeled Annual Average Total Phosphorus Concentration Changes in the Fraser River Basin

Station	Average Annual Total Phosphorus Concentrations, µg/L		Percent Change
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	
Average Year			
Fraser below Fraser WWTP	130	73	-44%
Ranch Creek	29	33	+15%
Crooked Creek	79	82	+3%
Fraser at Mouth	70	50	-28%
Dry Year			
Fraser below Fraser WWTP	160	84	-48%
Ranch Creek	29	33	+15%
Crooked Creek	82	85	+4%
Fraser at Mouth	82	54	-35%
Wet Year			
Fraser below Fraser WWTP	104	62	-40%
Ranch Creek	29	32	+12%
Crooked Creek	68	69	+2%
Fraser at Mouth	60	47	-22%

Notes:
µg/L = micrograms per liter
RFFA = reasonably foreseeable future action
WWTP = Wastewater Treatment Plant

The increases in total nitrogen and decreases in total phosphorus concentrations in the mainstem of the Fraser River would be moderate to major. The increases in total nitrogen and total phosphorus concentrations in Ranch Creek would be moderate. The increases in total nitrogen and total phosphorus concentrations in Crooked Creek would be minor to negligible. As discussed above, all of these impacts are primarily attributable to changes in WWTP flow rates (with population growth) and concentrations (with anticipated changes in treatment efficiency). Results from the Fraser nutrient mass-balance model were used as input for the Three Lakes Model.

e) Potential Impacts to WWTP Dischargers

To estimate potential changes in assimilative capacity, the acute and chronic low flows were calculated for Current Conditions (2006), Full Use of the Existing System, and Full Use with a Project Alternative with RFFAs (2032). CDPHE has modified an EPA program, DFLOW, for calculation of acute and chronic low flow (Pierce 2010). Table 4.6.2-15 shows the results of this program using the daily PACSM estimated flows for each condition and for each of the five WWTPs.

Table 4.6.2-15
Calculated Acute and Chronic Low Flow

Wastewater Treatment Plant	Current Conditions (2006)		Full Use of the Existing System		Full Use with a Project Alternative with RFFAs (2032)	
	Acute Low Flow (cfs)	Chronic Low Flow (cfs)	Acute Low Flow (cfs)	Chronic Low Flow (cfs)	Acute Low Flow (cfs)	Chronic Low Flow (cfs)
Winter Park Water and Sanitation District	2.8	2.8	2.0	2.6	2.0	2.6
Fraser Sanitation District	6.3	9.6	2.4	3.7	2.4	3.7
Tabernash	15.8	19.8	16	19.9	16	19.9
Devil's Thumb Ranch	0.4	0.4	0.4	0.5	0.4	0.5
Granby Wastewater Treatment Facility	13.6	19.7	14.9	19.4	15.1	19.4

As shown in Table 4.6.2-15, reductions in acute and/or chronic low flows are anticipated to occur between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) for Winter Park Water and Sanitation District, Fraser Sanitation District, and Devil's Thumb Ranch. Conversely, slight increases to acute and/or chronic low flows are anticipated to occur between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) for Tabernash, Devil's Thumb Ranch, and Granby Wastewater Treatment facilities. These slight increases in acute and chronic low flows are attributable to slight increases in average stream flows in October of dry years, at which times increased diversions would not occur under the Proposed Action with RFFAs (see Appendix H-1.50).

The Winter Park Water and Sanitation District and the Fraser Sanitation District are likely to have impacts to their WWTP discharge permits because of the estimated changes in acute and chronic low flow. The magnitude of the change in their discharge permits is unknown and is dependent on the ability of the existing plant to provide treatment in excess of permit requirements. If the proposed nutrient standards are promulgated, the wastewater plants may need upgrades to avoid experiencing impacts from lower flows. Any flow related impacts to discharge permits would be due to cumulative conditions and would be the result of lower flows in non-runoff months. The lower flows in non-runoff months would primarily be due to increased water use in Grand County as discussed in Section 4.6.1. The remaining plants are not likely to have impacts from the lower flows as the acute and chronic low flows are estimated to stay the same or increase under projected conditions.

f) Effects Due to Changes in Tributary Flows and Water Quality

Two flow conditions were used to evaluate potential impacts caused by changes in tributary water quality: runoff months and non-runoff months. During runoff months, increases in diversions by Denver Water through the Moffat Tunnel would occur. During non-runoff months, changes in flows between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) would occur, but these are primarily caused by changes from in-basin diversions as discussed in Section 4.6.1.

During non-runoff months, changes in flow occur between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) at Fraser River below Vasquez Creek (Node 2600) and Fraser River below St. Louis–Hammond Ditch No. 1 (Node 2700). These are summarized in Appendix H-2. These changes in flow would result from increased diversions from Vasquez Creek by Grand County Water and Sanitation District and increased diversions from the Fraser River by the Town of Fraser. When evaluating effects of changes in tributary water quality, Vasquez Creek would provide proportionally less water to the Fraser River than St. Louis Creek. The relative reduction in water from Vasquez Creek would result in increased iron and zinc concentrations, potentially leading to stream standard exceedances in Vasquez Creek. However, exceedances of stream standards in the Fraser River would not be anticipated as a result of the Proposed Action with RFFAs based on data for these constituents at water quality stations upstream of Vasquez Creek.

The change to copper concentrations is unknown, but copper concentrations in Vasquez Creek are suspected of being near the stream standard. The proportional contribution by Vasquez Creek and the resultant influence on the Fraser River would likely reduce copper concentrations. However, because the source of copper in the Fraser River is unknown (except for partial contribution of the Moffat Tunnel permitted discharge), the magnitude of the potential change in copper concentrations cannot be numerically quantified. Considering that water quality stations on the Fraser River downstream of St. Louis Creek are within stream standards, it is likely that water quality in St. Louis Creek is also within stream standards. Therefore greater relative flow from St. Louis Creek is not likely to cause the Fraser River to exceed stream standards.

During runoff months, the influence from Vasquez Creek would be similar during average and wet years with somewhat more influence during dry years. As noted above, copper concentrations may change but it is not possible to numerically quantify the magnitude using currently available data. Water quality in St. Louis Creek is likely within standards and therefore changes from St. Louis Creek would not likely cause exceedances of stream standards in the Fraser River. Segments of the Fraser River near Crooked Creek and Ranch Creek are noted in Section 3.2 to have had instances of stream standard exceedances for pH. Influences from Crooked Creek and Ranch Creek on these exceedances are unknown. Projected changes in flow from diversions in the Ranch Creek watershed would be less than 10% of total flow below Crooked Creek. Therefore, no changes in water quality below Crooked Creek are anticipated to be caused by changes in the percent of the flow contributed from Ranch Creek.

g) Effects on Vasquez Creek Caused by Increased Flows Through the Gumlick Tunnel

Diversions from the Williams Fork River Basin through the Gumlick Tunnel (also called the Jones Pass Tunnel) and the Vasquez Tunnel would increase under the Proposed Action with RFFAs. These increased water deliveries from one basin could change the water quality in the receiving basin. The changes in flow would be nearly identical for all action alternatives.

To determine potential impacts, two sets of data from Current Conditions (2006) were examined. The first was water quality in Vasquez Creek, both upstream and downstream of the tunnel discharge. Adequate data were not available through EPA's Storage and Retrieval Data Warehouse (STORET) or the USGS website, therefore Denver Water provided data from their operational records. The second set of data included potential changes in the water delivered through the Gumlick Tunnel.

The water quality data for Vasquez Creek are presented in Table 3.2-6. Those parameters indicating a change greater than 15% (upstream to downstream) are dissolved cadmium, dissolved copper, *Escherichia coli* (*E. Coli*), dissolved nickel, temperature, and dissolved zinc. Therefore, there would be a change in water quality that would potentially be caused by water deliveries through the Gumlick and Vasquez tunnels. These changes are individually discussed below.

- **Dissolved Cadmium** – Cadmium shows a decrease downstream of the tunnel discharge. However, the detection limit in the method used is 0.1 µg/L. Using CDPHE procedures, samples with values below detection limits were changed to “0” for statistical purposes. The actual change above and below the tunnel is likely very small because most data points are below detection limits, with one or two samples being slightly above detection limits at locations above the tunnel. Water quality data in the tunnel (Denver Water sample site “Vasquez Tunnel Outlet”) indicate a slightly higher value at the 85^{th} percentile (0.12 µg/L). Again, the detection limit was 0.1 µg/L and this value represents two samples being above detection limits. The stream standard is 0.55 µg/L. No change would occur with regard to cadmium due to changes in deliveries through the Gumlick and Vasquez tunnels.
- **Dissolved Copper** – Copper shows a decrease downstream of the tunnel discharge. Again, the detection limit is equivalent to the calculated 85^{th} percentile, 3 µg/L. The 85^{th} percentile value above and in the tunnel is calculated to be 0. However, similar to cadmium, these changes are likely because all values are near the detection limit. The stream standard for copper is 1.67 µg/L, which is less than the detection limit of the method used. Concentrations of copper for all three locations (above the tunnel discharge, at the diversion, and in the tunnel) are expected to be near the detection limit or below. No changes are expected with regard to copper due to changes in deliveries through the Gumlick and Vasquez tunnels.
- ***E. Coli*** – *E. Coli* shows an increase downstream of the tunnel discharge. The value in the tunnel is 0.75 (most probable number [MPN]/100 ml), which is very similar to the value above the tunnel discharge. *E. Coli* concentrations are affected by many factors, including the presence of wildlife. The stream standard for *E. Coli* is 126 MPN/100 ml. All three locations indicate water of pristine water quality. No change is expected with regard *to E. Coli* because of changes in deliveries through the Gumlick and Vasquez tunnels.
- **Dissolved Nickel** – Dissolved nickel shows a decrease downstream of the tunnel discharge. However, the detection limit for the various samples ranges from 0.8 to 2.0 µg/L. Therefore the decrease is likely a result of testing limits and the statistical methods used. The stream standard is 9.9 µg/L, which is well above any changes noted in the water quality data. No changes in dissolved nickel concentrations would occur as a result of changes in deliveries through the Gumlick and Vasquez tunnels.
- **Temperature** – Temperature increases in the downstream direction. This is to be expected as the stream descends to warmer elevations. The 85^{th} percentile for

temperature is well below the stream standard. No change is expected with regard to temperature because of changes in deliveries through the Gumlick and Vasquez tunnels.

- **Dissolved Zinc** – Dissolved zinc shows a decrease downstream of the tunnel discharge. The stream standard is 22 µg/L. The 85th percentile value is well within this limit both upstream and downstream of the tunnel. For all three sample locations, an unusually high value was reported on the same sample date (June 29, 2005), leading to suspicion with the data. This one sample date impacts the 85th percentile calculation as most samples had concentrations below the detection limit. Additionally, data taken in the Williams Fork River Basin on June 30, 2005, also resulted in unusually high values. The concentrations from the other sample dates are clustered around the detection limit. No change would be expected with regard to dissolved zinc due to changes in deliveries through the Gumlick and Vasquez tunnels.

All parameters evaluated were below drinking water standards with the exception of total coliform and turbidity. Turbidity is an indication of sediment and silt in the water and cannot be expected to approach zero, except after treatment. Drinking WTPs and the drinking water regulations focus on removal of turbidity with the understanding that natural waters would have varying degrees of turbidity. Coliform are a type of bacteria that occur both naturally with fecal coliform coming specifically from human and livestock waste. Coliform are measured in treated drinking water as an indicator of the presence of potentially harmful microscopic organisms. Again, all drinking WTPs and the drinking water regulations focus on inactivation of coliform and other pathogens with the understanding that natural waters would have some degree of microbial activity such as coliform. The measured values for coliform and turbidity in this water source indicate high quality water sources.

Potential changes in water quality in water diverted to the Gumlick Tunnel could impact water quality in Vasquez Creek. The water quality in the Gumlick and Vasquez tunnels would not be expected to change due to increased diversions. The diversions would continue to come from headwaters areas where water quality is generally high. No other inputs of water into the Fraser River Basin would occur under the Proposed Action with RFFAs. Therefore, negligible impact is expected on Vasquez Creek, and therefore also on the Fraser River, resulting from additional diversions through the Gumlick and Vasquez tunnels.

Conclusions for the Fraser River Basin

A summary of potential changes in water quality in the Fraser River Basin as a result of changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032) conditions follows:

- Potential changes in the concentrations of parameters of interest (copper, iron, pH, and zinc) are not quantified due to lack of long-term and reliable data.
- Ranch Creek is anticipated to be impacted from negligible to moderate levels with regard to temperature impairment. Application of the available data and methods indicate a negligible level of impact would be expected. Ranch Creek is currently listed on the Section 303(d) List and more rigorous analysis considering a wider range of factors that affect stream temperatures may yield additional impacts ranging up to a

moderate level if adequate data and methods can be developed. In the absence of this type of analysis, the transition to Full Use of the Existing System, RFFAs, and the Proposed Action are not expected to increase the frequency of stream standard exceedances.

- Fraser River Sections 10b and 10c are anticipated to be impacted from negligible to moderate levels with regard to temperature impairment. Application of the available data and methods indicate a negligible level of impact would be expected. These Fraser River segments are currently listed on the Section 303(d) List and more rigorous analysis considering a wider range of factors that affect stream temperatures may yield additional impacts ranging up to a moderate level if adequate data and methods can be developed. In the absence of this type of analysis, the transition to Full Use of the Existing System, RFFAs, and the Proposed Action are not expected to increase the frequency of stream standard exceedances.
- A potential effect on the Moffat Tunnel discharge permit is possible due to reduced acute and chronic low flows. The magnitude of the impact is not quantified due to lack of long-term and reliable data.
- Changes in nutrient levels, specifically total nitrogen and total phosphorus are anticipated to result in moderate to major impacts for the Fraser River and Ranch Creek.
- Potential changes in discharge permits for the Winter Park Water and Sanitation District and Fraser Sanitation WWTPs are expected but the magnitude of change is unknown. This change would be primarily due to lower flows in non-runoff months as a result of increased water use in Grand County.
- The percent of the river that would be effluent contributed by the Winter Park, Tabernash, Devil's Thumb, and Granby WWTPs is expected to remain in compliance with the current permitted limit for projected flows under Full Use with a Project Alternative with RFFAs (2032) conditions.
- The percent of the river that would be effluent contributed by the Fraser Sanitation District WWTP flows is projected to be greater than current permitted percentages under Full Use with a Project Alternative with RFFAs (2032) conditions. The impact of this change is not quantified because the ability of the plant's current treatment processes to respond to more stringent requirements is unknown and extent of future treatment regulations are uncertain.
- There are no cumulative impacts projected due to changes in the tributary water quality.
- There are no cumulative impacts projected due to changes in deliveries through the Gumlick and Vasquez tunnels.

Williams Fork River

The Proposed Action with RFFAs may have the following potential water quality impacts to the Williams Fork River upstream and downstream of the Williams Fork Reservoir:

a) ***Reduction in Assimilative Capacity for Climax Mine Discharges***: A reduction in dilution of the Climax Mine discharge would increase contaminant concentrations to harmful levels and potentially impacts the Climax Mine discharge permit due to flow changes.

b) Effects Due to Changes in Tributary Flows and Water Quality

c) Potential Effects on Dissolved Oxygen and Temperature Due to Changes in Reservoir Releases

Each of these potential water quality impacts is discussed below:

a) Reduction in Assimilative Capacity for Climax Mine Discharges

The discharge from Climax Mine is governed by CDPHE Discharge Permit No. CO0000230, which allows a maximum discharge of 0.1 mgd (or about 0.155 cfs). When CDPHE performs an anti-degradation review, one test to determine significance is dilution. The minimum dilution rate at which a new or increased discharged would no longer be considered significant is 100:1. Therefore, an insignificant degradation would result for flows greater than 15.5 cfs. The PACSM simulation looked at 30 years in which flow was projected to occur less than 15.5 cfs and demonstrated occurrences of 848 days under Current Conditions (2006), and 852 days under Full Use with a Project Alternative with RFFAs (2032) conditions.

The estimated acute and chronic low flows were calculated using DFLOW (Pierce 2010). The estimated acute low flow, using the PACSM daily data would be 13.1 cfs under both Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032). The estimated chronic low flow, using the PACSM daily data would be 14.7 cfs under Current Conditions (2006) and 19.0 cfs under Full Use with a Project Alternative with RFFAs (2032). Therefore, there are no projected changes in water quality in the Williams Fork River due to influences from the Climax Mine discharge or changes in flow. Additionally, there would be no expected impacts to the Climax Mine discharge permit due to projected changes in flow in the Williams Fork River under the Proposed Action with RFFAs.

b) Effects Due to Changes in Tributary Flows and Water Quality

Water quality data and the calculated stream standards for each tributary are discussed in Section 3.2. The Middle Fork Williams Fork River is upstream of the sampling point on the mainstem, however, a number of parameters show an increase in concentration downstream of the confluence of the Middle Fork. Therefore, change in flow from each tributary has the potential to change water quality in the Williams Fork River. Water quality is not anticipated to change with regard to the Proposed Action with RFFAs since all parameters discussed herein are well below stream standards except dissolved copper and DO. The focus of this subsection is therefore on dissolved copper and DO.

Dissolved copper concentrations range from below detection limits at the headwater streams to 1.1 mg/L at Sugarloaf Campground, to below detection limits again at Leal. This is most likely caused by the samples being very close to the detection limit. For the upstream tributaries, 10 of 11 samples were below the detection limit for dissolved copper. At Sugarloaf Campground, nine of 11 samples were below the detection limit for dissolved copper. Typically, copper sources originate from underlying geology or abandoned mining operations. From the USGS topographic maps of the Williams Fork River Basin, the only identified mining operations in the headwaters are on Bobtail and Jones creeks. Therefore, copper concentration would not likely exceed the stream standard with changes in flow.

The year-round standard for DO is 6.0 mg/L, and the spawning standard is 7.0 mg/L. For two sites on the mainstem of the Williams Fork River, DO concentrations are around the 15th percentile. For both of these sites, two low readings were taken, one in October 2003 and the other in October 2004. Samples on the headwater tributaries were taken on different days. DO changes throughout a stream's length are anticipated with fluctuations influenced by organic matter concentrations, temperature, rate of mixing, and many other factors. The reason(s) for the two low samples recordings at the two sites are unknown, but with samples taken in October, increased organic matter from leaf fall is possible. Samples collected during the following two Octobers had adequate DO concentrations, implying that the earlier low DO readings coincided with low flow periods. Therefore, flow changes in October were evaluated.

When comparing average year flow rates in the upstream reach of the Middle Fork under Current Conditions (2006) to flow rates under Full Use with a Project Alternative with RFFAs (2032) conditions, a decrease in average flow was observed from 1.2 cfs to 0.8 cfs or about 37% in an average year. The analysis showed no change during dry or wet years. At Darling Creek (downstream of the Middle Fork), little to no changes in flow during any condition were observed. Reduced flows combined with the right conditions for leaf fall have the potential to exacerbate occasional low DO conditions that have been documented. However, the actual impact is unknown as lower flows also provide for additional surface area to volume, allowing for greater potential oxygen transfer from the air.

c) Potential Effects on Dissolved Oxygen and Temperature Due to Changes in Reservoir Releases

Downstream of Williams Fork Reservoir, the Grand County Stream Management Plan identifies a number of sites where DO samples were below regulatory standards of 6.0 mg/L. The purpose for the regulatory standard on the Williams Fork is two-fold. There is a minimum of 6.0 mg/L year-round, and during spawning months (April through May and September through early November), the regulatory minimum is 7.0 mg/L. Data provided by GCWIN (Bailey 2010) provides the following information on ambient water quality downstream of the reservoir:

- 15th percentile DO for all data: 6.3 mg/L
- 15th percentile DO for all spawning months: 6.8 mg/L
- 15th percentile DO for spring spawning: 7.0 mg/L
- 15th percentile DO for fall spawning: 5.5 mg/L

The data shows the river to be outside regulatory standards for DO during fall spawning periods. The cause is unknown but may be the result of reservoir releases during the time of fall reservoir turnover. In October of average and wet years, an increase in releases from William Fork Reservoir occurs under Full Use with a Project Alternative with RFFAs (2032) conditions compared to Current Conditions (2006). Releases in September and November would be similar under the Proposed Action with RFFAs when compared to

Current Conditions. If the cause of low DO is due to reservoir releases, added monitoring and controls of reservoir releases will be valuable in improving low DO levels.

Water temperature below Williams Fork Reservoir would not increase from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032). Temperature of released or bypassed water is controlled by temperature of the reservoir at the elevation from which water is released. Williams Fork Reservoir levels would be higher under Full Use with a Project Alternative with RFFAs (2032) than under Current Conditions (2006) due to the expiration of Big Lake Ditch lease and discontinuation of “10,825” Water releases (see Section 4.3.1). Therefore, reservoir temperature at depth would not increase, and released water may be colder under Full Use with a Project Alternative with RFFAs (2032) than under Current Conditions (2006).

Generally, flows below the reservoir under Full Use with a Project Alternative with RFFAs (2032) conditions would be greater than those under Current Conditions (2006) except during August and September of about half the years. This increase would occur due to termination of the Big Lake Ditch lease on Williams Fork water, making more water available above Williams Fork Reservoir. Furthermore, greater releases for substitution and exchange would also account for flow increases below Williams Fork Reservoir in late summer of some years. Average change in flow would increase or stay the same for all months except August when there would be a 3% reduction in flow.

Conclusions on Potential Changes in Water Quality in the Williams Fork River

A summary of potential changes in water quality in the Williams Fork River as a result in changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032) follows:

- No impacts are anticipated to the Climax Mine discharge permit.
- The impact of the Full Use with a Project Alternative with RFFAs (2032) on low DO concentrations near specific sampling stations is unknown.
- No impacts other than potential changes in DO concentrations from changes in tributary contributions are anticipated.

Colorado River

The Proposed Action with RFFAs may have the following potential water quality impacts to the Colorado River:

a) ***Potential Changes in Water Temperature***: These include potential increases in the frequency that the temperature standard is exceeded between Windy Gap and Kremmling, currently listed on the Section 303(d) List for temperature.

b) ***Potential Changes to WWTP Discharge Permit and Treated Wastewater Contributions***: These include the potential for more stringent discharge permits for WWTPs, necessitating capital expenditures for upgrades by local governments.

c) ***Potential Effects on Aquatic Life Use***

d) ***Potential Changes to Manganese Concentrations Downstream of 578 Road***

Each of these potential water quality impacts are discussed below:

a) Potential Changes in Water Temperature

The Colorado River, as noted in Section 3.2, is listed on the Section 303(d) List with exceedances of temperature standards downstream of Granby Reservoir. To evaluate the Colorado River segments with these exceedances and also identify other stream segments where water temperatures may approach or exceed standards potentially due the Proposed Action with RFFAs, information was developed for temperature measurements near or exceeding the standard (within 1˚C). GCWIN stations were used because they record data every 15 to 60 minutes throughout the summer months and span various periods of record. This information was not screened for days on which air temperature was greater than the historical 90th percentile, although State regulations provide for an exception to water quality standards when air temperature is greater than the historical 90th percentile for that date. This information is presented in Table 4.6.2-16.

Table 4.6.2-16
Temperature at GCWIN Stations on the Colorado River

Station	Period of Record	Daily Maximum				Maximum Weekly Average Temperature			
		No. of Samples that Exceed State Std.	No. of Samples that are within 1° of State Std.	Max. Daily Max. °C	State Std. °C	No. of Samples that Exceed State Std.	No. of Samples that are within 1° of State Std.	MWAT (for POR) °C	State Std. °C
Colorado River below Windy Gap	2005-2009	0	0	22.1	23.8	1	9	18.5	18.2
Colorado River above Hot Sulphur Springs	2006-2009	6	13	25.4	23.8	6	5	19.0	18.2
Colorado River below Byers Canyon	2008-2009	0	0	21.2	23.8	0	0	17.2	18.2
Colorado River at Lone Buck	2006-2008	0	0	22.8	23.8	7	6	19.2	18.2
Colorado River above Kid Pond	2005-2008	0	0	22.2	23.8	0	2	17.8	18.2
Colorado River at CR 3	2007-2009	0	1	23.2	23.8	6	6	19.5	18.2
Colorado River at Con Ritschard Ranch	2006-2009	0	1	23.1	23.8	0	2	17.7	18.2
Colorado River at Kemp-Breeze Ditch	2007-2009	0	0	20.8	23.8	0	0	16.1	18.2
Colorado River at Highway 9 Bridge	2006-2010	0	0	22.8	23.8	10	7	19.9	18.2

Samples that approach or exceed the State temperature standard for DM or MWAT (acute and chronic, respectively) are discussed below. These samples are also highlighted in italics in Table 4.6.2-6.

- **Colorado River at Windy Gap** – Three of the 10 MWATs that approached the State standard occurred during weeks where the air temperature was greater than the 90th percentile. All MWATs that exceeded or approached the State standard occurred in August.
- **Colorado River above Hot Sulphur Springs** – Two of the DMs that approached the State standard occurred on days where the air temperature was greater than the 90th percentile. Two of the MWATs that exceeded the State standard and one of the MWATs that approached the State standard occurred on days where the air temperature was greater than the 90th percentile.
- **Colorado River at Lone Buck** – Three of the MWATs that exceeded the State standard and one of the MWATs that approached the State standard occurred on days where the air temperature was greater than the 90th percentile.
- **Colorado River above Kid Pond** – There were no exceedances of State standards. Occasions of the MWAT approaching the State standard did not coincide with air temperature greater than the 90th percentile.
- **Colorado River at CR3** – The DM that approached the State standard occurred on a day where the air temperature equaled the 90th percentile. Four of the MWATs that exceeded the State standard and one of the MWATs that approached the State standard occurred on days where the air temperature was greater than the 90th percentile.
- **Colorado River at Con Ritschard Ranch** – There were no exceedances of State standards. Occasions of the MWAT approaching the State standard did not coincide with air temperature greater than the 90th percentile.
- **Colorado River at Highway 9 Bridge** – One MWAT occurred on a day where the air temperature equaled the 90th percentile.

The previous section that discussed potential changes in water temperature in the Fraser River showed that a direct statistical correlation between stream flow and water temperature could not be used to reliably predict changes in stream temperatures. Evaluations similar to those in the Fraser River section of this EIS were developed for the GCWIN stations on the Colorado River below Windy Gap. The methodology was the same as that used for the Fraser River Basin. The data sources were (period of analysis was 2005-2010):

- GCWIN Station: COR-blwWG – 15-minute water temperature
- USGS Station: #09034250 (Colorado River at Windy Gap) – daily flow and maximum daily water temperature for missing data at COR-blwWG
- NOAA Weather Station: #59096 (Williams Fork Dam) – maximum daily air temperature

Figure 4.6.2-20 shows the flow versus water temperature for the Colorado River below Windy Gap. The R-squared value is low at 0.017. The slope of the best fit line, at 0.004, also indicates very little correlation in this dataset between flow and water temperature. As discussed in the Fraser River section, air temperature, as shown in Figure 4.6.2-21, has a much better correlation with an R-squared of 0.74 and a slope of the best fit line of 0.59. Figure 4.6.2-22 indicates that water temperature closely follows air temperature, as shown for the Fraser River.

Similar to the Fraser River, the Colorado River is on the Section 303(d) List and additional evaluation was performed to determine the degree of correlation between flow and water temperature for narrow bands of air temperature. The methodology used for evaluation was the same as that used for the Fraser River.

Figure 4.6.2-20
Relationship Between Flow and Water Temperature for Colorado River below Windy Gap

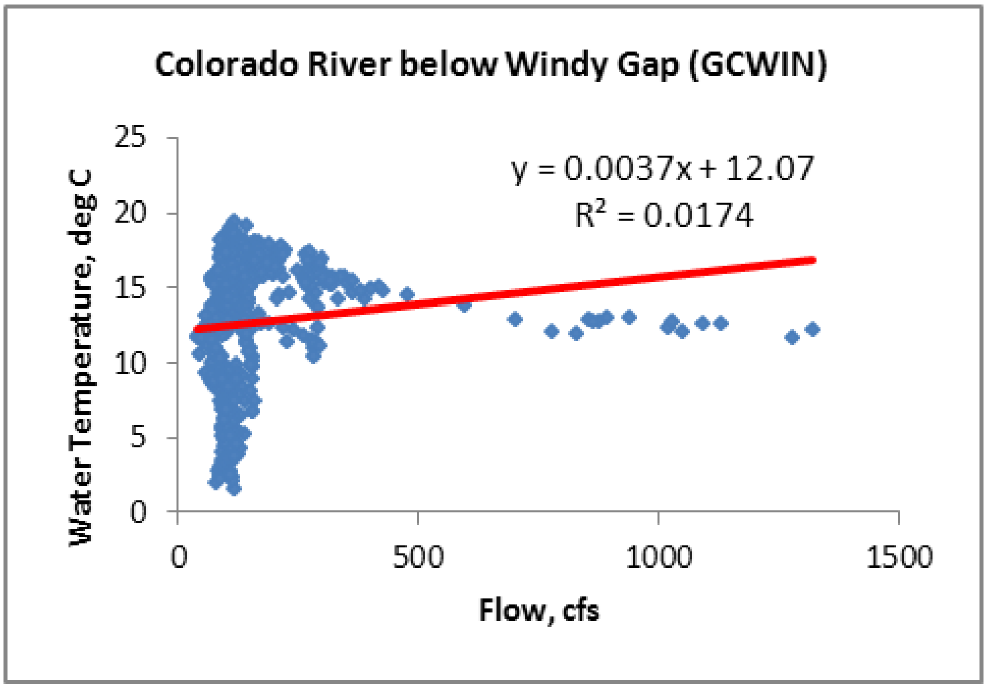


Figure 4.6.2-21
Relationship Between Air Temperature and Water Temperature for the Colorado River below Windy Gap

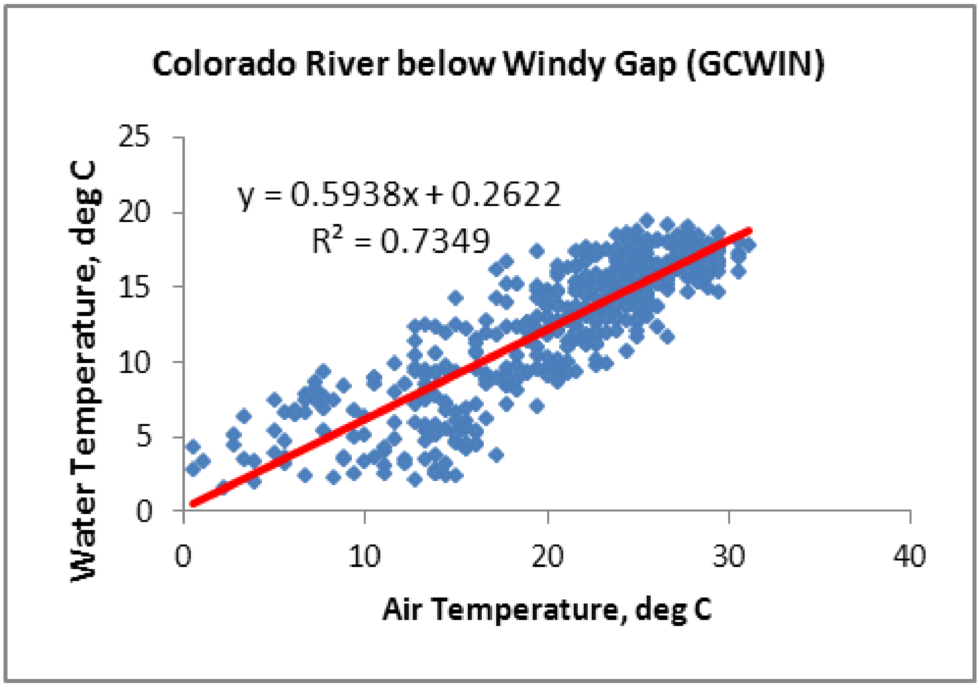


Figure 4.6.2-22
Typical Water Temperature, Air Temperature, and Flow Over Time

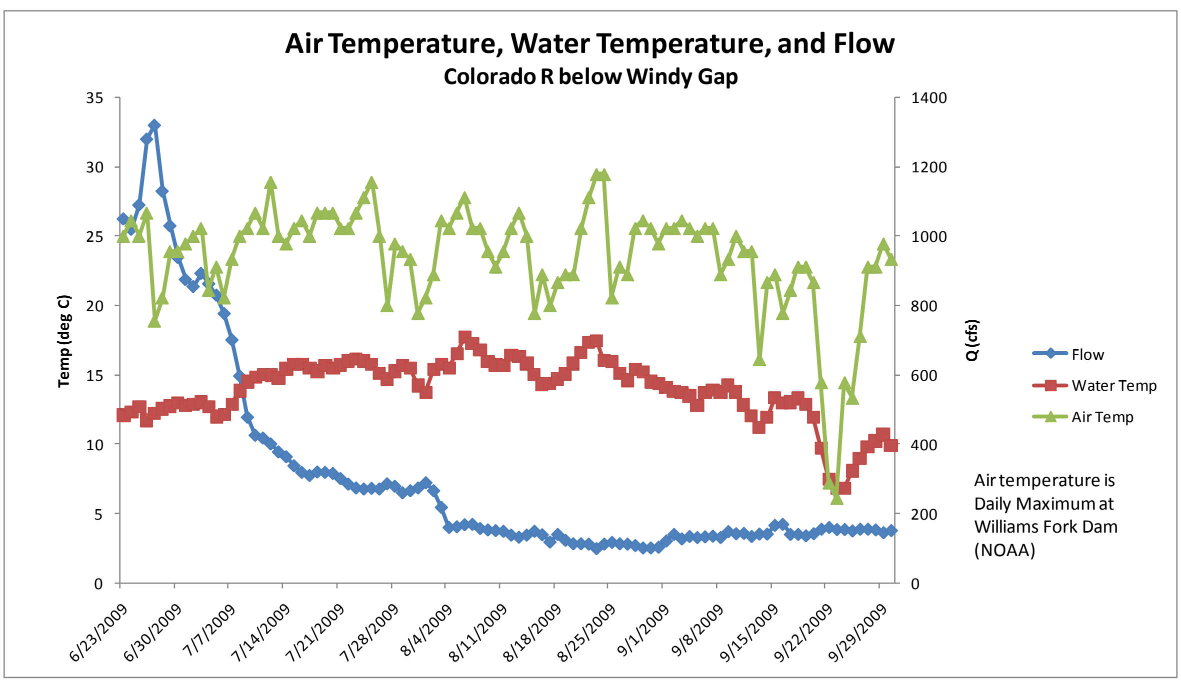


Figure 4.6.2-23 includes graphs for various temperature ranges versus flow for the Colorado River below Windy Gap. This site has not exceeded the State standard for DM temperature in any data evaluated but has exceeded the MWAT as detailed in Section 3.2. The July and August flows evaluated in this additional analysis had a minimum of 87 cfs and an 85th percentile of 331 cfs. This site also had the strongest consistency between air temperature groups and as well as the highest R-squared values. However, the range of slopes for this site is -0.02 to -0.002, with an average of -0.01, indicating very little correlation between water temperature and stream flow for this dataset. Additionally, slopes of the best fit lines (an average of 0.1°C water temperature change for every 10 cfs in flow change) indicate that potential trends identified in this dataset could be at least partially due to the magnitude of the measurement error for water temperature data and are likely within the accuracy of the data. The R-squared values ranged from 0.007 to 0.81. The strongest R-squared value occurred for the air temperature group 84°F. The slope for the best fit line at this air temperature group was -0.017. This slope is likely within the accuracy of the water temperature data (0.17°F for every 10 cfs). The next strongest correlation was for the air temperature group 86-89°F. The slope for the best fit line at this temperature group was -0.016 with an R-squared of 0.77. Again, the slope of the best fit line is likely within the accuracy of the water temperature data.

Similar to Ranch Creek, additional analysis was performed to determine the relationship between water temperature and flow rate. On the first day of water temperature exceeding the MWAT, the flow rate was evaluated to determine if it increased or decreased and at what percentage. There were a total of 28 occurrences in the period of record where one or more days were above the MWAT. Of these, 18 had a decrease in flow rate from the previous day, with an average decrease in flow of less than 9%. Of the 10 days that had an increase in flow, the average increase in flow was about 10%.

Similar to Ranch Creek, an evaluation was conducted of the number of days with high water temperature (exceeding the MWAT standard) that occurred during periods of low flow (defined as flow less than 15th percentile). If a strong correlation exists between stream flow and water temperature, a disproportionate number would be expected to occur on days of low stream flow.

A total of 147 days for the period of record had water temperature in excess of the MWAT. Of these, 31 days, or about 21%, occurred on days when stream flow was below the 15th percentile.

The above evaluations show that the available data do not support a direct statistical correlation between water temperature and flow.

Figure 4.6.2-23
Mean Daily Flow Rate Versus Water Temperatures for the Colorado River below Windy Gap (No Exceedance of State Acute Water Temperature Standard at this Site)

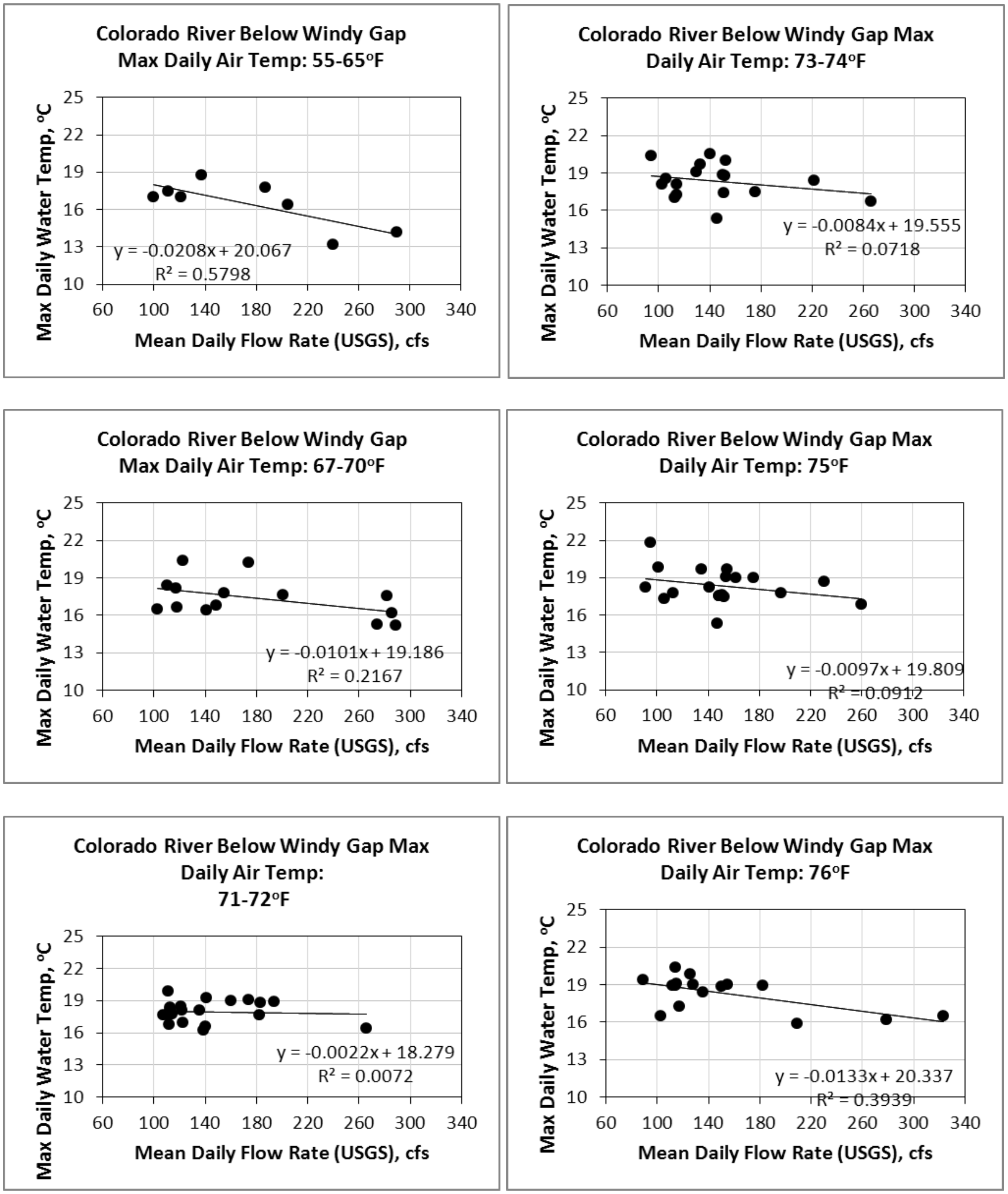
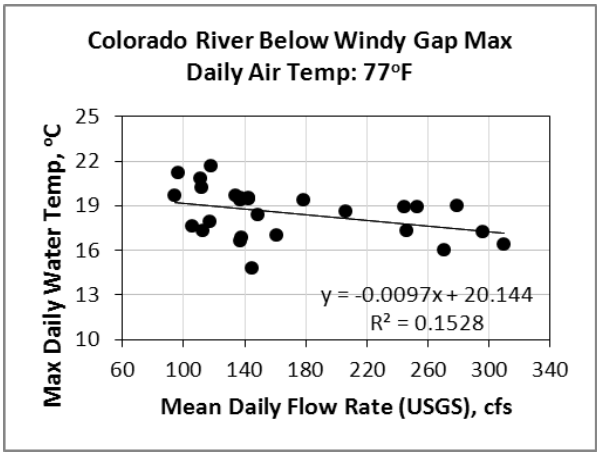
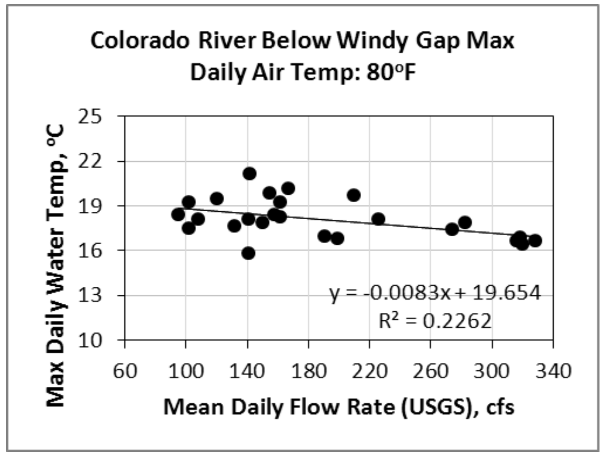
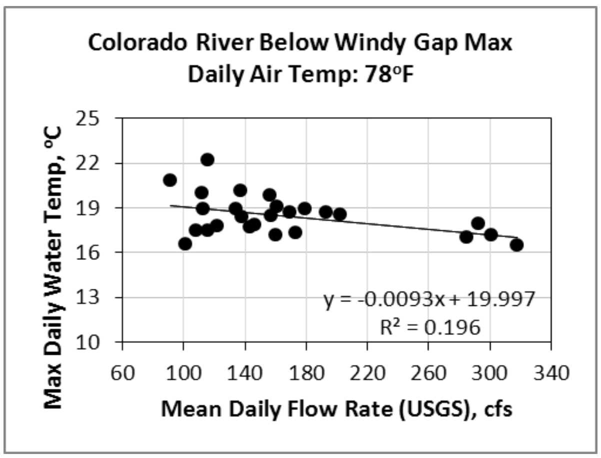
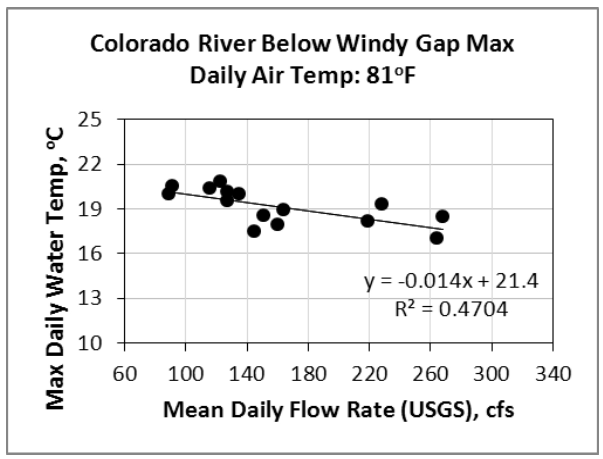


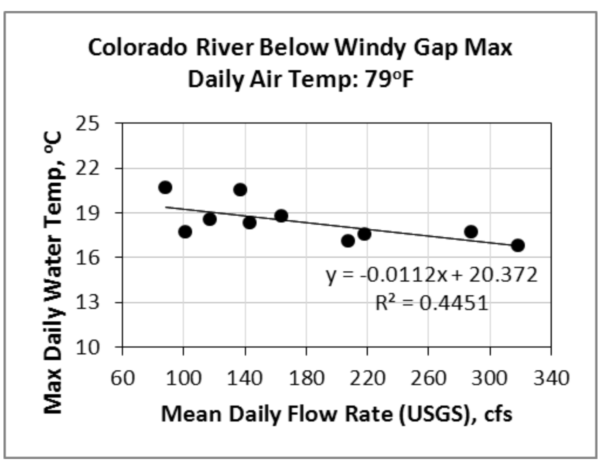
Figure 4.6.2-23 (continued)
Mean Daily Flow Rate Versus Water Temperatures for the Colorado River below Windy Gap (No Exceedance of State Acute Water Temperature Standard at this Site)











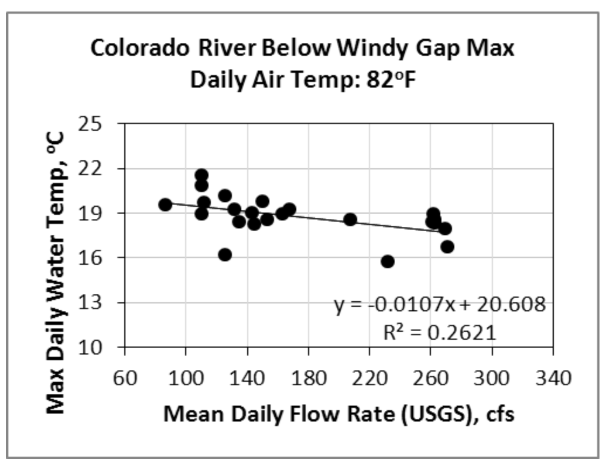
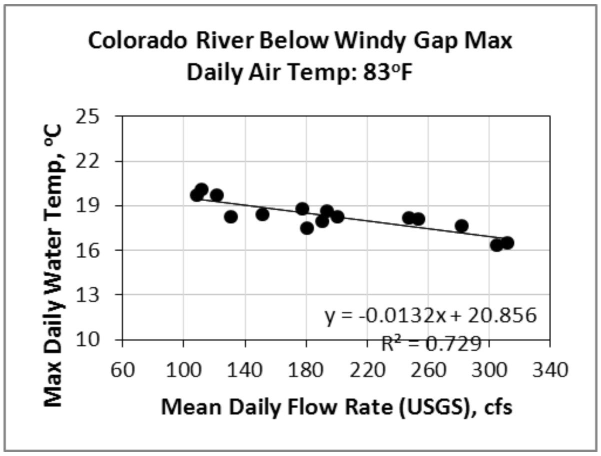
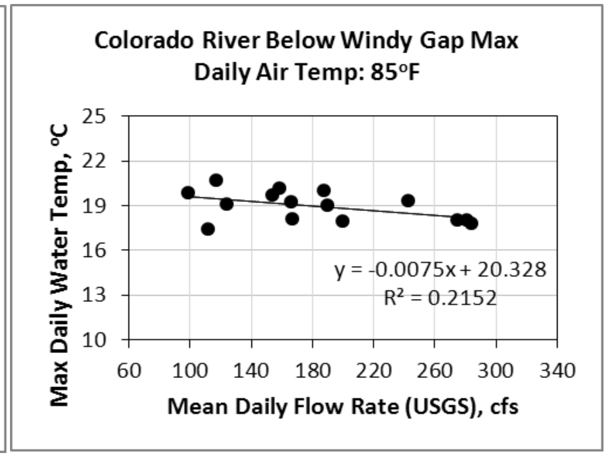
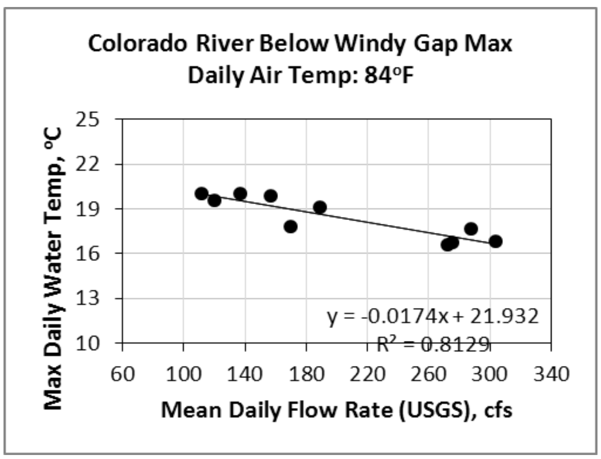
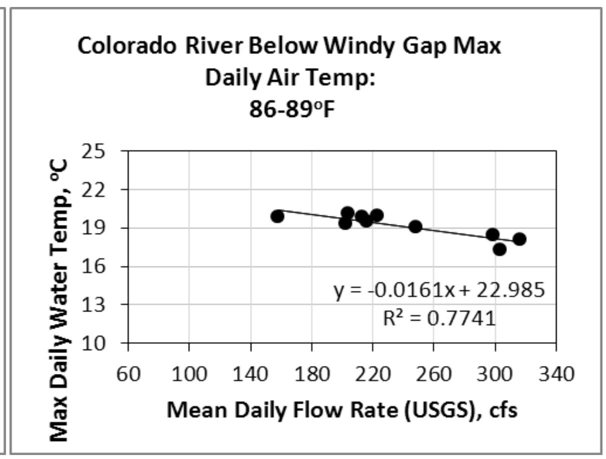


Figure 4.6.2-23 (continued)
Mean Daily Flow Rate Versus Water Temperatures for the Colorado River below Windy Gap (No Exceedance of State Acute Water Temperature Standard at this Site)









In summary, differences between water temperatures under Current Conditions (2006) relative to water temperatures under Full Use with a Project Alternative with RFFAs (2032) conditions are expected to be minor. For the Colorado River, where listed in Regulation 93 on the Section 303(d) List (CDPHE 2012a), application of the available data and methods indicate a negligible level of impact would be expected. This river section is currently on the Section 303(d) List and more rigorous analysis considering a wider range of factors that affect stream temperatures may yield additional impacts ranging up to moderate if adequate data and methods can be developed. In the absence of this type of analysis, the transition to Full Use of the Existing System, Proposed Action with RFFAs, are not expected to increase the frequency of stream standard exceedances.

b) Potential Changes to WWTP Discharge Permit and Treated Wastewater Contributions

Hot Sulphur Springs WWTP is a minor discharger and has a greater than 1:100 dilution ratio. The current permitted discharge is 0.09 mgd (0.14 cfs). Changes in low flow would need to be extreme to have any impact to the Hot Sulphur Springs permit. Acute low flow was calculated using daily data from PACSM Node 1400, Colorado River at Hot Sulphur Springs. The lowest calculated acute low flow was 26.7 cfs, significantly more than a 1:100 dilution ratio. Therefore, impacts to the Hot Sulphur Springs WWTP discharge permit due to changes in flow between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) conditions are not anticipated. Because the Hot Sulphur Springs WWTP is such a small discharger, changes in water quality in the Colorado River are not anticipated due to projected changes in flow.

c) Potential Effects on Aquatic Life Use

The upper Colorado River from the outlet of Windy Gap Reservoir to the 578 Road Bridge is listed on the Monitoring and Evaluation List for Aquatic Life Use (CDPHE 2012a). A discussion of the Aquatic Life Use listing and potential impacts related to the Proposed Action with RFFAs is presented in Section 4.6.11.

d) Potential Changes to Manganese Concentrations Downstream of 578 Road

Manganese concentrations exceed the secondary drinking water standard at two sites in Table 3.2-12. Additionally, the Colorado River from the 578 Road bridge to the confluence with the Blue River is on the Section 303(d) List for manganese exceeding the drinking water standard (CDPHE 2012a). The drinking water standard is a secondary standard, suggested by the EPA to limit aesthetic concerns and customer complaints; there is no concern with human health. Manganese is easily removed in conventional drinking WTPs via blending, aeration, green sand filtration, or precipitation/sedimentation/filtration. The concentrations noted in Table 3.2-12 and by the State are well below the aquatic life standard (typically above 1,000 µg/L but dependent on hardness). The source of the manganese is unknown, and therefore effects from Full Use with a Project Alternative with RFFAs (2032) are difficult to characterize. Two public drinking water suppliers use this section of the Colorado River: Town of Hot Sulphur Springs and Town of Kremmling. Manganese levels are not anticipated to affect either supplier. Treatment to reduce manganese concentrations is voluntary and at the discretion of water suppliers.

Conclusions on Potential Changes in Water Quality in the Colorado River

Potential changes in water quality in the Colorado River due to changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032) conditions include:

- Negligible to moderate impacts would occur to temperature in the Colorado River. Impacts are characterized as ranging up to moderate because the Colorado River is already on the Section 303(d) List; however, an increase in the frequency of days in which the DM or the MWAT exceed the standard is not anticipated based on currently available data and methods.
- No impacts to WWTPs are anticipated as the only permitted WWTP has a current dilution rate of greater than 1:100.
- No significant impacts to WTPs are anticipated from changes in manganese concentrations as the concentrations are already exceeding secondary drinking water standards, and the conventional treatment processes are applicable and can be implemented at the discretion of the plant owners.
- No impacts to aquatic life are anticipated from changes in manganese concentrations as current concentrations are orders of magnitude below aquatic life stream standards.

Blue River

The Proposed Action with RFFAs may have the following potential water quality impacts to the Blue River:

a) Changes in Discharge Permits for WWTPs, Necessitating Possible Plant Upgrades

b) Changes in Water Quality Due to Changes in Tributary Flows and Water Quality

c) Changes in Water Quality Related to Treated Wastewater Discharges

d) Changes in Water Quality Due to Changes in the Water Quality and/or Release Patterns of Dillon Reservoir and/or Green Mountain Reservoir

Each of these potential water quality impacts are discussed in detail below.

a) Changes in Discharge Permits for WWTPs, Necessitating Possible Plant Upgrades

The only discharge permit downstream of Dillon Reservoir that would be impacted by changes in flows is the Joint Sewer Authority (JSA) municipal WWTP. Potential impacts to this plant would be:

- Changes in acute and chronic low flow that would change the permit limits.
- Changes in acute and chronic low that would change monitoring requirements in the permit.

The JSA WWTP's existing permit is tiered by effluent flow, with the largest effluent tier providing for up to 4 mgd discharge of treated effluent. The acute low flows are 52 cfs and chronic low flows are 62 cfs. Under the existing permit, the percent of the stream that is treated effluent under chronic low flow conditions is 9.7%. At percentages greater than 10%, monitoring requirements for toxicity testing would change. Additionally, at higher effluent flows or lower stream flows, the JSA WWTP would need to provide additional treatment for disinfection and copper removal.

To evaluate potential impacts to the JSA WWTP, the acute and chronic low flows were estimated for Current Conditions (2006), Full Use of the Existing System, and Full Use with a Project Alternative with RFFAs (2032) using the modeled PACSM daily flows. These flows were estimated on a 7 day running average to simulate how Denver Water determines releases (see Section 4.6.1). DFLOW, the CDPHE modified EPA program, was used to calculate acute and chronic low flow (Pierce 2010). DFLOW was used herein along with the average daily PACSM estimated flows for each condition and results are shown in Table 4.6.2-17. Under Full Use of the Existing System and Full Use with a Project Alternative with RFFAs (2032), both acute and chronic low flows would increase when compared to Current Conditions (2006). Therefore, no changes to the JSA WWTP discharge permit are anticipated. The total number of days at very low flows (under 45 cfs) would decrease from 23 days under Current Conditions (2006) to 7 days under Full Use of the Existing System and Full Use with a Project Alternative with RFFAs (2032). The permit may be changed due to the projected growth in the service area and resultant increase in effluent being discharged.

The calculated low flows shown in Table 4.6.2-17 are less than existing low flows with the current JSA WWTP permit. The JSA WWTP discharge point is located below both Straight Creek and Willow Creek, and while Table 4.6.2-17 does not reflect the additional flow from these tributaries, the JSA permit *does* include the tributary flow. The low flows shown in Table 4.6.2-17 are within 5% of calculated low flows from historic USGS gage information collected for the Blue River between 1997 and 2007. No additional monitoring would be anticipated for the JSA due to changes in Dillon Reservoir releases and potential increases in low flows.

Table 4.6.2-17
Calculated Acute and Chronic Low Flow below Dillon Reservoir

Wastewater Treatment Plant	Current Conditions (2006)		Full Use of the Existing System		Full Use With a Project Alternative with RFFAs (2032)	
	Acute Low Flow (cfs)	Chronic Low Flow (cfs)	Acute Low Flow (cfs)	Chronic Low Flow (cfs)	Acute Low Flow (cfs)	Chronic Low Flow (cfs)
Joint Sewer Authority*	44	48	45	49	45	49

Note:
*Low flows calculated using Dillon Reservoir outflow from PACSM results as discussed in Section 4.6.1.

b) Changes in Water Quality due to Changes in Tributary Flows and Water Quality

The Proposed Action with RFFAs would not affect flows in tributaries to the Blue River. Therefore, changes in water quality of the tributaries would not change as a result of the Proposed Action with RFFAs.

c) Changes in Water Quality related to Treated Wastewater Discharges

The existing permit for the JSA WWTP uses 52 cfs as an acute low flow. Using this acute low flow and 80% of current permitted discharge, the permit would remain in compliance up to an effluent content of 9.5% in the Blue River. The method of comparing to 80% of permitted discharge is based on:

- State regulations stipulate that when WWTPs reach 80% of capacity, design for plant expansion should begin and new construction should start prior to reaching 95% of capacity. Using 80% of plant capacity is a more conservative (lower) estimate of permitted capacity where permits are written for 100% of the permitted capacity. Most WWTP entities strive to be good stewards and typically have construction completed prior to reaching 95%.
- The current percentage of the river that contains wastewater effluent is estimated using 80% of the current permitted capacity. This provides for a conservative (lower) estimate of the allowable effluent when determining a significant change.

Future conditions were evaluated using estimated wastewater discharge. The estimated wastewater discharge in 2032 was 5.6 mgd, based on the estimated population increase for the Town of Silverthorne, per the Silverthorne Comprehensive Plan (December 2001). Table 4.6.2-18 lists the percent of effluent under Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) for months in which Dillon Reservoir discharges would change more than 10%.

Table 4.6.2-18
Estimated Percent JSA Wastewater Treatment Plant Treated Effluent of Dillon Reservoir Releases

Month	Percent of Dillon Reservoir Releases that are Wastewater		Percent Change from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032)
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	
Average Years			
October	11%	14%	27%
November	14%	15%	7%
April	11%	12%	9%
May	3%	4%	33%
June	1%	2%	100%
July	3%	4%	33%
August	6%	8%	33%
September	10%	12%	20%
Dry Years			
June	14%	17%	21%
July	6%	12%	100%
August	6%	10%	67%

Table 4.6.2-18 (continued)
Estimated Percent JSA Wastewater Treatment Plant Treated Effluent of Dillon Reservoir Releases

Month	Percent of Dillon Reservoir Releases that are Wastewater		Percent Change from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032)
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	
Wet Years			
October	7%	17%	143%
November	10%	16%	60%
December	13%	15%	15%
January	15%	16%	7%
February	15%	16%	7%
March	15%	16%	7%
April	5%	6%	20%
May	1%	2%	100%
June	1%	1%	0%
July	1%	2%	100%
August	3%	3%	0%

For the Blue River downstream of Dillon Reservoir, the maximum percent effluent would be 15.2% under Current Conditions (2006) and 17.3% under Full Use with a Project Alternative with RFFAs (2032) conditions. The table shows a number of months in which the change in percent effluent in Dillon Reservoir releases would change more than the 10% threshold used in this EIS to identify areas of potential significant effect. Therefore, further consideration was given to the environmental effects of the increased effluent in the reservoir releases. When the percentage of wastewater increases in a stream or river, there are potential increases in organic matter, nutrients, and oxygen demand. However, any actual degradation in stream water quality is dependent on level of treatment provided at the WWTPs and on the receiving stream’s water quality prior to the increase in effluent discharge. Although the impact to the Blue River cannot be definitively determined with the available data, the potential cumulative impacts relative to Dillon Reservoir releases would be minor to moderate relative to the general characteristics of the wastewater discharges and current water quality of the Blue River.

d) Changes in Water Quality Due to Changes in the Water Quality and/or Release Patterns of Dillon Reservoir and/or Green Mountain Reservoir

When changes in releases from Dillon Reservoir are significant (greater than 10%), the potential to change water quality downstream exists. Evaluation was conducted between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) conditions during months in which significant changes in Dillon Reservoir releases were anticipated. Table 4.6.2.4-19 lists the results and the calculated percent changes.

Table 4.6.2-19
Potential Changes in Release Patterns of Dillon Reservoir

Month	Percent Flow in the Blue River from Dillon Reservoir, Downstream of Boulder Creek*		Percent Change from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032)
	Current Conditions (2006)	Proposed Action with RFFAs (2032)	
Average Year Conditions			
October	66%	61%	8%
November	65%	63%	-3%
April	60%	57%	-5%
May	69%	57%	-17%
June	74%	65%	-12%
July	61%	55%	-10%
August	59%	52%	-12%
September	60%	56%	-7%
Dry Year Conditions			
June	30%	26%	-13%
July	61%	45%	-26%
August	65%	52%	-20%
Wet Year Conditions			
October	72%	49%	-32%
November	68%	57%	-16%
December	71%	68%	-4%
January	68%	68%	-0%
February	73%	72%	-1%
March	76%	74%	-3%
April	73%	68%	-7%
May	82%	73%	-11%
June	74%	77%	4%
July	68%	65%	-4%
August	66%	64%	-3%

Note:
*Calculated from PACSM Nodes 4250 and 4500. Months in which releases from Dillon Reservoir change greater than +/- 10% are shown.

Flows during many months indicate a greater than 10% change in relative contributions from sources in the Blue River downstream of Boulder Creek. A water quality change in the Blue River is also a possibility due to tributaries having variable water quality. Recent water quality data (post-2000) is not available on tributaries throughout the Blue River Basin downstream of Dillon Reservoir; however, most of the watershed is located in National Forest where anthropogenic impacts to water quality are minimal.

The Blue River from the outlet of Dillon Reservoir to the confluence with North Rock Creek is listed on the Monitoring and Evaluation List for Aquatic Life Use (CDPHE 2012a). A discussion of the Aquatic Life Use listing is presented in Section 3.11.

Conclusions on Potential Changes in the Blue River

A summary of potential changes in the Blue River resulting in changes between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) conditions include:

- A slight increase would occur in the acute and chronic low flow rates due to increased releases from Dillon Reservoir. No impacts to the JSA permit are anticipated as a result of changes in releases from Dillon Reservoir.
- Negligible changes would occur in water quality in the Blue River due to changes in tributary contributions.
- The water quality changes caused by changes in wastewater portions in the Blue River are unknown. Estimated change between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) ranges from a decrease of 13% to an increase of over 150%. Actual changes to water quality are highly dependent on treatment capabilities. Changes in treatment processes may be needed to meet regulations and conditions unrelated to changes in flow conditions.

Muddy Creek

The Proposed Action with RFFAs may have the following potential water quality impacts to Muddy Creek:

a) ***Potential Increase in Temperature Standard Exceedances Downstream of Wolford Mountain Reservoir***

b) ***Potential Impacts to WWTP Permits***

c) ***Changes in Water Quality Caused by Changes in Treated Wastewater Volume***

d) ***Changes in Water Quality Caused by Changes in Releases from Wolford Mountain Reservoir***

Each of these potential water quality impacts are discussed in detail below.

a) ***Potential Increase in Temperature Standard Exceedances Downstream of Wolford Mountain Reservoir***

Temperatures in Muddy Creek below Wolford Mountain Reservoir are influenced by reservoir releases. Prior to any modification of the Moffat Collection System, temperatures would change in the future due to changes in the operation of the reservoir for the 10,825 Water Program (see Section 4.3.2), expanded contract deliveries to West Slope users, and due to Denver Water's substitution for Blue River diversions. Flows would increase in dry years, for all months except August. In wet years, outflows would be reduced in June and July, but would otherwise be similar to Current Conditions (2006).

The MWAT for the period of record is 20.2°C and the maximum DM is 22.8°C for the period of record. The two MWAT exceedances are the only MWATs that approach or exceed the standard. There were 10 DM values that approach or exceed the standard. Two of the DMs and none of the MWATs occurred on days where the air temperature was above the 90th percentile, and some occurred on days that had air temperatures less than 60°F. Evaluations suggest that the release depth in the reservoir (the elevation of water released from the reservoir) is more important than flow or air temperature. With regard to temperature, the quantity of flow would therefore be less important than the elevation from which the releases are made.

The reservoir has four outlet gates at twenty-foot intervals in elevation (Stevens and Sprague 2001). In a 2001 study, the top layer of the reservoir was found to be near or above the temperature standard, therefore downstream exceedances of temperature standard could be expected if releases are made from the uppermost gate. Generally, releases have been made from the bottom and uppermost gates during the months of May through August (Stevens and Sprague 2001). It is not known whether changes in release rates affect the operator's ability to manipulate use of the bottom gate to achieve water temperature objectives. Such operation would require cooperation of the Colorado River Water Conservation District who has responsibility for Wolford Mountain Reservoir operations. There would be no impact from changes in operations of Wolford Mountain as a result of the Proposed Action with RFFAs.

b) Potential Impacts to WWTP Permits

The greatest potential impact to the Kremmling WWTP would be a change in the assimilative capacity used to determine discharge limitations. To evaluate potential changes in assimilative capacity, the acute and chronic low flows were calculated for Current Conditions (2006), Full Use of the Existing System, and Full Use with a Project Alternative with RFFAs (2032). DFLOW, the CDPHE modified EPA program, was used to calculate acute and chronic low flow (Pierce 2010). DFLOW was used herein along with the average daily PACSM estimated flows for each condition and results are shown in Table 4.6.2-20.

Table 4.6.2-20
Calculated Acute and Chronic Low Flow at Wolford Mountain Dam Outlet

	Current Conditions (2006)		Full Use of the Existing System		Full Use With a Project Alternative with RFFAs (2032)	
	Acute Low Flow (cfs)	Chronic Low Flow (cfs)	Acute Low Flow (cfs)	Chronic Low Flow (cfs)	Acute Low Flow (cfs)	Chronic Low Flow (cfs)
Wolford Mountain Dam Outlet	3.5	6.8	10.3	23	10.3	12.9

Acute and chronic low flows would increase under Full Use with a Project Alternative with RFFAs (2032) when compared to Current Conditions (2006). There would be no impact to the Kremmling WWTP as the assimilative capacity under Full Use with a Project Alternative with RFFAs (2032) conditions would increase.

c) Changes in Water Quality Caused by Changes in Treated Wastewater Volume

As noted in Table 4.6.2-20, acute and chronic low flows in Muddy Creek would increase under Full Use with a Project Alternative with RFFAs (2032). As shown in Appendix H-2, flows would decrease more than 10% downstream of Wolford Mountain Reservoir during the following months: November and August of average years, August of dry years, and November and April of wet years. The Kremmling WWTP has a permitted discharge of 0.3 mgd. Using 80% (for reasons noted above in the Fraser River section) and the acute low flow of 3.5 cfs shown in Table 4.6.2-20 the percent wastewater under Current

Conditions (2006) is 10.6%. Calculated percent wastewater flows for the months with notable changes are shown in Table 4.6.2-21.

Table 4.6.2-21
Changes in Percent Wastewater for Months with Decreases in Flow of 10% or More

Month	Percent of Muddy Creek that is Wastewater*		Percent Change from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032)
	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)	
Average Years			
November	1.9%	2.5%	32%
August	0.8%	1.0%	25%
Dry Years			
August	0.5%	0.6%	20%
Wet Years			
November	1.0%	2.1%	110%
April	0.5%	0.9%	80%

Note:
*Calculated using PACSM flow from Wolford Mountain, Node 1600.

Months that are not shown in Table 4.6.2-21 are projected to have increases in flow from Wolford Mountain Reservoir or insignificant decreases in flow. Actual percentages of wastewater contribution would be less because the Kremmling WWTP discharges into Muddy Creek downstream of Wolford Mountain Dam and additional tributary inflow. Therefore, no changes would occur to water quality given that the percentages of wastewater flow in the months of note would be significantly less than the currently permitted conditions.

d) Changes in Water Quality Caused by Changes in Releases from Wolford Mountain Reservoir

Potential water quality changes would occur from changes in Wolford Mountain Reservoir releases due to changes in proportional contributions between the dam and downstream tributaries. Water quality parameters of concern, as shown in Table 3.2-10, include arsenic, temperature, sulfate, and total dissolved solid (TDS). With the exception of temperature, these are likely derived from soils in the Alkali Slough, a tributary to Wolford Mountain Reservoir (Stevens and Sprague 2001). Changes in reservoir releases would not likely change parameter concentrations since the reservoir attenuates spikes in concentrations resulting from snowmelt or storm runoff.

Conclusions on Potential Changes in Water Quality on Muddy Creek

The following summarizes potential changes in water quality in Muddy Creek as a result in changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032) conditions:

- Temperature downstream of Wolford Mountain Dam would be directly related to the reservoir level from which water is released. Wolford Mountain Dam is not operated by Denver Water and no impacts would result from implementing the Proposed Action with RFFAs.

- Greater assimilative capacity for the Kremmling WWTP would be anticipated under Full Use with a Project Alternative with RFFAs (2032) conditions.
- There would be no anticipated impact to Muddy Creek due to changes in discharge of treated effluent.
- There would be no anticipated impact due to changes in releases from Wolford Mountain Reservoir.

South Boulder Creek

Potential impacts on water quality in South Boulder Creek upstream of Gross Reservoir would be attributed to changes in source water and impacts associated with Moffat Tunnel discharge. Potential water quality impacts include:

a) Changes in Concentrations of Contaminants in Source Water

b) Potential Impacts Related to the Moffat Railroad Tunnel Discharge Permit

c) Potential Changes in South Boulder Creek below Gross Reservoir

Each of these potential water quality impacts are discussed in detail below:

a) Changes in Concentrations of Contaminants in Source Water

Table 3.2-18 lists the water quality upstream and downstream of the Moffat Tunnel. Four constituents are discussed as they differ from upstream to downstream of the Moffat Tunnel. These changes are likely due to the influence of the imported water. The first constituent is cadmium where sample results both upstream and downstream were very near the detection limit. Upstream readings had 4 of 9 samples below detection level, while downstream readings had 5 of 9 samples below detection level, however, all samples were within the stream standard. Discharges through the Moffat Tunnel would, therefore, not likely change cadmium concentrations significantly.

The second constituent is *E. Coli*. The actual concentrations of *E. Coli* are insignificant, to the point of being negligible. As measured in most probably number per 100 ml (MPN), the stream standard is 126. With geometric mean values of 0.8 and 2.1, the change would not be significant.

The third constituent is Manganese which was well within the stream standard. With the 85^{th} percentile values at less than 0.7% of the stream standard, the anticipated change would not be significant.

Uranium, the fourth constituent, was also well within the stream standard, with 85^{th} percentile values at less than 1.5% of the stream standard. The 85^{th} percentile value is also well within the drinking water standard of 30 µg/L. The maximum increase in flow between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) conditions is 100%, or a doubling of contributions from the Moffat Tunnel. Even under these conditions, concentrations of uranium would be well below stream standards and drinking water standards. Therefore, the change would not be significant.

Parameters with drinking water standards were also evaluated. Sodium was the only parameter that would undergo a significant change. However, the 85th percentile value is well below the advisory drinking water limit. Therefore, the change would not be significant.

b) Potential Impacts Related to the Moffat Railroad Tunnel Discharge Permit

The Moffat Railroad Tunnel Discharge Permit allows for discharge of railroad tunnel seepage water to either the Fraser River or South Boulder Creek under permit number CO-0047554. Discharge to South Boulder Creek is limited to 0.5 mgd, or about 0.77 cfs. Because this flow is seepage water, the maximum flow is not expected to increase.

The Moffat Railroad Tunnel discharge into South Boulder Creek occurs just downstream of the tunnel. To estimate Project impacts on dilution in South Boulder Creek, flow through the railroad tunnel was reviewed and the low flow deliveries through the railroad tunnel were estimated. Acute low flow deliveries were estimated to change from zero under Current Conditions (2006) to 2.2 cfs under Full Use with a Project Alternative with RFFAs (2032). Chronic low flow deliveries were estimated to change from 1.4 cfs under Current Conditions (2006) to 8.6 cfs under Full Use with a Project Alternative with RFFAs (2032). There would be no adverse cumulative impacts to water quality caused by changes in flow through the Moffat Railroad Tunnel when combined with potential discharges from the Moffat Railroad Tunnel. Additionally, no impacts are anticipated to the Moffat Railroad Tunnel Discharge Permit.

c) Potential Changes in South Boulder Creek below Gross Reservoir

Only very limited water quality data are available for South Boulder Creek between Gross Reservoir and Eldorado Springs for evaluation of Current Conditions (2006); however, it is possible to broadly anticipate relative changes in water quality due to Full Use with a Project Alternative with RFFAs (2032) conditions. Possible impacts with regard to water quality for South Boulder Creek downstream of Gross Reservoir include:

- Changes in Gross Reservoir water quality
- Changes in Gross Reservoir outflow water temperature
- Impacts to water providers due to changes in water quality
- Impacts to WWTP dischargers

Changes in Gross Reservoir Water Quality

Short-term changes in water quality in Gross Reservoir due to land inundation are expected to be minor, with possible increases occurring in TOC and nutrient concentrations. These changes are anticipated to be minimized through grubbing and land clearing prior to inundation, as described in Chapter 2. In response, corresponding short-term, negligible to minor increases in productivity may occur in South Boulder Creek downstream of Gross Reservoir. These changes would not impact impaired or potentially impaired segments farther downstream due to the numerous water withdrawals between Gross Reservoir and the mouth of South Boulder Creek.

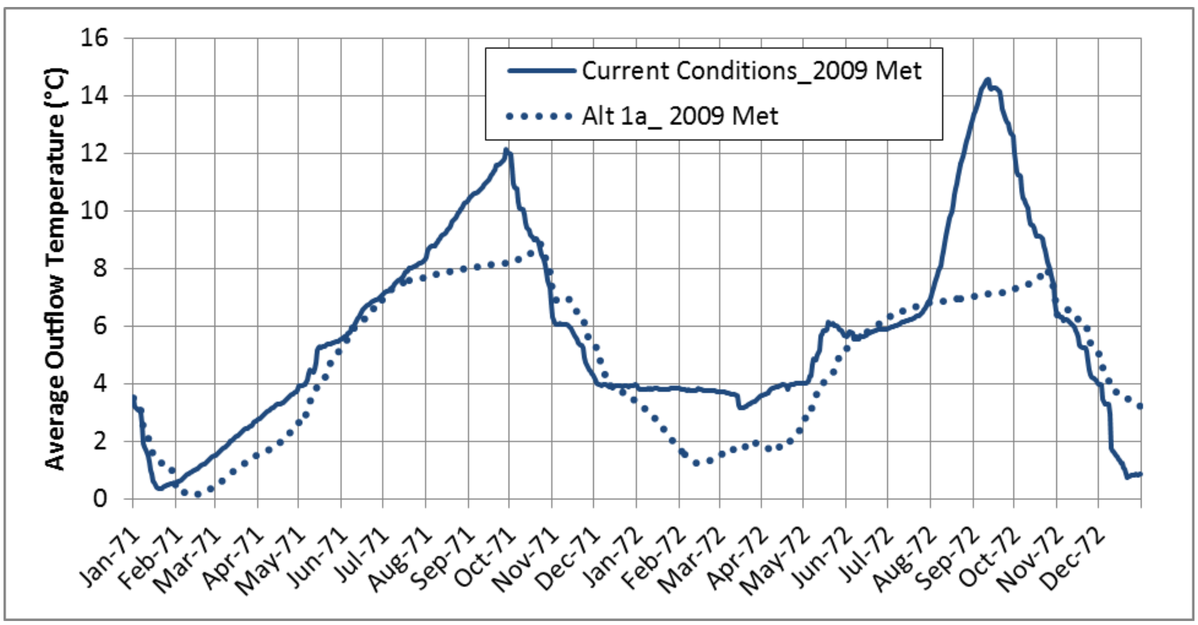
Changes in Gross Reservoir Outflow Water Temperature

As first noted in Section 4.6.2.1.1, a two-dimensional, numerical, hydrodynamic and temperature model of Gross Reservoir was developed to simulate potential effects on outlet water temperatures for the Proposed Action. Model development, calibration, and application are documented in detail in Hawley et al. (2013), which is presented in full in Appendix E-5.

The calibrated model was applied to simulate outflow temperatures for the Proposed Action. Results were compared to simulated outflow temperature results for Current Conditions (2006). A two-year period of the PACSM hydrology (1971-1972) was simulated. This time period was selected because it included 1972, the year with the maximum difference (between Current Conditions and the Proposed Action in average summertime [July-September]) water surface elevation. The simulation period also included a year close to the median difference (1971). Each simulation was run with 2009 meteorological inputs (cooler air temperatures) and 2012 meteorological inputs (warmer air temperatures).

Simulation results demonstrate that the outflow temperature response did not vary much based on meteorological inputs. The larger effect on outflow temperatures was in response to the reservoir expansion. Model results predicting outflow temperatures for 1971-1972 for the Proposed Action and for Current Conditions (2006) are shown in Figure 4.6.2-24.

Figure 4.6.2-24
Simulated Outflow Temperatures from Gross Reservoir for Base285 and Alternative 1a, 1971 and 1972, 2009 Meteorological Inputs



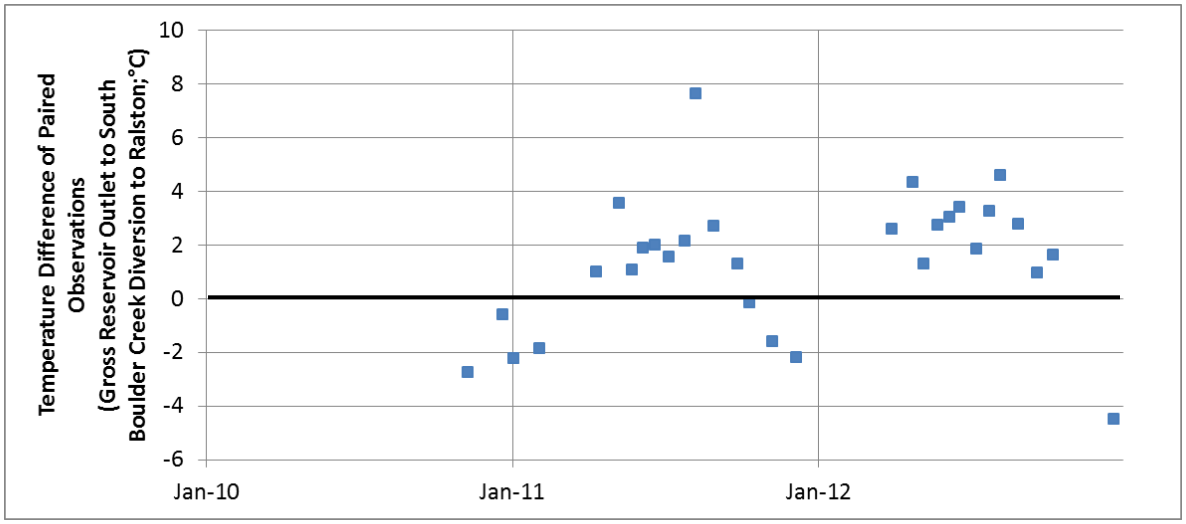
The model predicts cooler summer and peak outflow temperatures for the Proposed Action. The largest decrease in peak temperature for 1972 was simulated to be -6.6°C (for the 2009 meteorological inputs). The largest decrease in peak temperature for 1971 was simulated to be -4.0°C (for 2012 meteorological input). These simulated decreases in peak temperatures result in maximum outflow temperatures that do not go above 9°C under the Proposed Action, even over a range of meteorological inputs. Table 4.6.2-22 provides summary statistics of the outflow temperature results for the full simulation period of 1971 through 1972.

Table 4.6.2-22
Summary of 1971 and 1972 Outflow Temperature Differences for Simulated Alternatives

Metric	1971 through 1972 (2009 Meteorological Inputs/2012 Meteorological Inputs)
Difference in Average Annual Outflow Temperature (Alternative 1a versus Current Conditions)	-1.1°C / -0.9°C
Difference in July-September Average Outflow Temperature (Alternative 1a versus Current Conditions)	-2.4°C / -2.2°C
Current Conditions Maximum Outflow Temperature	14.6°C / 14.6°C
Alternative 1a Maximum Outflow Temperature	8.9°C / 8.3°C

With respect to South Boulder Creek below Gross Reservoir, the limited set of water temperature observations and the lack of adequate cross-section data do not support development of a dynamic temperature model for that reach. An empirical review of available data was conducted to assess the potential warming of outflow water that could be expected in summer months between the Gross Reservoir outlet and the South Boulder Creek Diversion to Ralston Reservoir (WS-RL-002). Figure 4.6.2-25 presents the difference between the available 30-paired (in-time) observations, with positive values showing warming between the Gross Reservoir outlet and WS-RL-002. Note that temperature observations at WS-RL-002 were only available as whole numbers in degrees Celsius, limiting resolution. Average summertime (July-September) warming over this reach was 2.9°C.

Figure 4.6.2-25
Observed Temperature Difference between Gross Reservoir Outlet and South Boulder Creek at Ralston Diversion



Effects on summertime water temperature in South Boulder Creek between Gross Reservoir and the South Boulder Creek Diversion Dam are predicted to be moderate to major. A discussion of any aquatic life effects related to these temperature predictions is presented in Section 4.6.11.1.

Impacts to Water Providers Due to Changes in Water Quality

Because of the short-term changes noted above, the Moffat WTP would likely experience short-term increases in TOC. TOC is a concern because of the potential formation of disinfection byproducts during treatment and distribution. Optimization of conventional treatment is generally sufficient to provide adequate removal of TOC. Other changes in treatment processes would not be anticipated.

Impacts to WWTP Dischargers

The most likely impact to WWTP dischargers would be attributed to changes in flow, particularly decreases in flow. Two permitted wastewater dischargers exist downstream of Gross Reservoir to SH 93 (downstream of the Project area); the Eldorado Springs WWTP, with a maximum permitted flow of 0.032 mgd (0.050 cfs), and the San Souci Mobile Home Park, with a maximum permitted flow of 0.018 mgd (0.028 cfs). San Souci Mobile Home Park is located downstream of Eldorado Springs. The PACSM at Node 57180, South Boulder Creek near the Eldorado Springs gage, provided the lowest monthly flow of 6.9 cfs under Current Conditions (2006) and 8.3 cfs under Full Use with a Project Alternative with RFFAs (2032) conditions. Both dischargers are minor dischargers with flow rate less than the 100:1 dilution test as used by CDPHE for determination of anti-degradation. The lowest monthly flow would increase under the Proposed Action with RFFAs and no potential impact to either WWTP would be anticipated.

Conclusions on Potential Changes in Water Quality in South Boulder Creek

The following summarizes potential changes in water quality in South Boulder Creek anticipated as a result in changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032) conditions:

- No water quality impacts are anticipated in South Boulder Creek from increased diversions through the Moffat Tunnel.
- No impacts are anticipated to the Moffat Railroad Tunnel discharge permit.
- Short-term minor increases in nutrients could lead to minor increases in biological productivity downstream of Gross Reservoir.
- Optimization of treatment processes at the Moffat WTP would be needed to address short-term changes in TOC from water quality changes in Gross Reservoir during the initial filling.
- No impacts to WWTP discharge permits are anticipated as both permitted discharges have a dilution rate greater than 100:1.

North Fork South Platte River

Potential water quality impacts to the North Fork South Platte River from changes in flow between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032) include the following:

a) Changes in Dillon Reservoir Water Quality

b) Changes Downstream of Roberts Tunnel Caused by Altered Diversions Through the Roberts Tunnel

c) Changes in Source Water Contributions (Roberts Tunnel Versus Tributary Flow)

d) Impacts to WWTP Dischargers

Each of these potential water quality impacts are discussed in detail below.

a) Changes in Dillon Reservoir Water Quality

Water quality in Dillon Reservoir is not expected to change. Therefore, water quality in the North Fork South Platte River would not be expected to change due to changes in the quality of water delivered through Roberts Tunnel.

b) Changes Downstream of Roberts Tunnel Caused by Altered Diversions Through the Roberts Tunnel

The PACSM results show a significant change in flow through Roberts Tunnel when comparing Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032). In general, flows would be significantly lower in the winter and significantly higher in the summer. Annual flows would increase significantly, about 25% in average and dry years and 17% in wet years.

Water quality changes would result from the proportional changes in river contributions from Roberts Tunnel deliveries and from Geneva Creek (just downstream of Roberts Tunnel). Water quality data upstream and downstream of the confluence with Geneva

Creek was used to evaluate potential impacts. This data was presented in Section 3.2 where a number of parameters show a significant change (an increase or decrease greater than 15%) from the assumed influences of Roberts Tunnel water deliveries. Each of these parameters are discussed below.

- **Boron** – Downstream of Roberts Tunnel discharge, the 85th percentile concentration for boron increases 83% where the stream standard for boron is 750 µg/L. Using anti-degradation criteria, 15% of the difference ([750 – 4 µg/L] multiplied by 0.15) is 112 µg/L. Although the recorded change is 82.5%, the concentration downstream of the tunnel would be significantly less than this at 7.3 µg/L. Therefore, any increase or decrease in flow through Roberts Tunnel would not likely change the concentration of boron greater than 112 µg/L. Therefore, no change in water quality is expected with regard to boron.
- **Copper** – At the upstream site, the 85th percentile concentration for copper was above stream standard while at the downstream site, a 79% reduction in concentration occurred meeting the stream standard of 10.6 µg/L. An increase in hardness causes this change. Downstream of Roberts Tunnel, the stream was in compliance with regulatory levels. Copper levels appear to be heavily influenced by Roberts Tunnel deliveries and any change in flow would potentially alter copper concentration. This impact was noted as a decrease in 85th percentile concentration for periods in which flow was predicted to increase, and was noted as an increase over existing concentrations for those periods in which flow was predicted to decrease. It was also noted that the stream standard for copper appears to be influenced by Roberts Tunnel deliveries due to the changes in hardness. Whether or not the copper concentration would exceed regulatory standards are unknown because the stream standard varies with hardness.
- ***E. Coli*** – Although the geometric mean for *E. Coli* decreases 19% downstream of the tunnel, both upstream and downstream ambient conditions are less than 1% of the stream standard. Therefore, any change in flow through the tunnel would not significantly change the concentration of *E. Coli*. *E. Coli* is bacteria whose counts vary with time, wildlife influences, and other causes. Therefore, no change is anticipated with regard to *E. Coli*.
- **Iron, dissolved** – The stream standard for dissolved iron is 0.3 mg/L. Upstream of the tunnel the 85th percentile concentration was 0.23 mg/L and downstream of the tunnel, the 85th percentile concentration for iron decreased 65% to 0.08 mg/L. This impact is noted as a decrease in 85th percentile concentration for those periods in which flow was predicted to increase and was noted as an increase over existing concentrations for those periods in which flow was predicted to decrease. The impact would not be significant as the concentration would remain below regulatory standards.
- **Manganese, dissolved** – The stream standard for dissolved manganese is 1,096 µg/L. At the 85th percentile, concentration for manganese decreases 32% downstream of the tunnel. Using CDPHE guidance for anti-degradation, the downstream concentration would need to increase by 183 µg/L (15% of 1,096-88 µg/L) to cause degradation. As the upstream, undiluted concentration is well below this level (130 µg/L), no change would be expected from an increase or decrease in flow.

- **Nickel, dissolved** – The upstream standard is 18.4 µg/L while the downstream standard increases to 29.0 µg/L because of the increased hardness concentrations downstream of the tunnel. At the 85th percentile, concentration for nickel decreases 49% downstream of the tunnel. When applying the CDPHE anti-degradation guidance, increases of more than 3.4 µg/L would result in degradation. With upstream concentrations significantly above downstream concentrations and an allowable increase of only 3.4 µg/L, a change is possible. This potential impact is noted as a decrease in the 85th percentile concentration for those periods in which flow would increase. The impact would be an increase over existing concentrations for those periods in which flow from the tunnel are predicted to decrease. The regulatory standard differs upstream and downstream of the tunnel as tunnel deliveries impact the hardness. This change would not be considered a significant impact because nickel concentrations are expected to remain below regulatory standards.
- **Uranium, dissolved** – The stream standard is 388 µg/L and at the 85th percentile concentration for uranium increases 133% downstream of the tunnel. Both upstream and downstream concentrations are under 1% of the standard. Therefore, no change in uranium concentration would be expected from an increase or decrease in flow.

The North Fork South Platte River is a direct water source for two drinking water providers: Bailey Water and Sanitation District (serving a population of 390) and Shawnee Water Conservation Area (serving a population of 86). Additionally, the North Fork South Platte River is an indirect source for users along the South Platte River downstream of the confluence. A change in the drinking water parameters would not indicate an impact. However, these parameters are discussed below for informational purposes. Drinking water parameters are listed in Table 3.2-19.

- **Barium, dissolved** – The 85th percentile both upstream and downstream is less than 2.5% of the drinking water standard. No change is expected.
- **Sodium, dissolved** – The 85th percentile downstream is greater than upstream (9.3 and 8.0 mg/L respectively). Both values are less than the EPA advisory level of 20 mg/L. However, sodium is on the contaminant candidate list (EPA 2010c). Therefore, although sodium increases downstream, no impact would occur.
- **Total Coliform** – The geometric mean decreases downstream of the tunnel. Both upstream and downstream of the tunnel, total coliform levels are relatively low. WTPs are designed to remove and inactivate total coliform through a multiple barrier approach and no impact would occur.
- **Turbidity** – Turbidity is a measure of particles in water and is an indication of clarity. Turbidity decreases downstream of the Moffat Tunnel. Similarly to total coliform, WTPs are designed to remove turbidity through multiple processes. Clarity can be important to water species, however at the turbidity levels noted upstream and downstream, little to no visual difference could be discerned and therefore no impact was found.
- **Aluminum, dissolved** – The 85th percentile upstream of Roberts Tunnel is greater than the secondary drinking water level. This secondary level is set for aesthetic reasons. Therefore, during periods where flows from Roberts Tunnel decrease, aluminum

concentrations may increase to greater than secondary drinking water levels. However, none of the water providers who use the South Platte River downstream of the North Fork South Platte River have historically experienced issues with aluminum which indicates dilution further downstream brings concentrations within secondary levels. Therefore, no impact was found.

c) Changes in Source Water Contributions (Roberts Tunnel Versus Tributary Flow)

Predicted flow changes result in decreases in the winter and increases in the spring and summer. Evaluation for both types of changes in flow are discussed. The biggest impact on water quality would be the change in percent contribution by deliveries through Roberts Tunnel. Water quality changes would result from the proportional changes in river contributions from Roberts Tunnel deliveries and from Geneva Creek (just downstream of Roberts Tunnel). These contributions were examined in average, dry, and wet years.

In average years, the percent contribution from Roberts Tunnel would decrease by 9 to 13% during the months of November through March under the Proposed Action with RFFAs when compared to Current Conditions (2006). During spring runoff months of May through July, the percent contribution from Roberts Tunnel increases by 65 to 122% as compared to Current Conditions (2006). The greatest increase would occur in May with an increased flow of 122%. The annual deliveries would increase approximately 9% with the change in proportional contribution from Roberts Tunnel.

In dry years, the percent contribution from Roberts Tunnel changes by greater than 10% in May, June, and July, with increases ranging from 19 to 25%. Annual deliveries would increase about 5% under Full Use with a Project Alternative with RFFAs (2032) with the change in contribution from Roberts Tunnel.

In wet years, the percent contribution from Roberts Tunnel would decrease by 4 to 28% in November through April. In May through October, the increase ranges from 34 to 478%. The annual average percent contribution would be 5% greater under Full Use with a Project Alternative with RFFAs (2032) as compared to Current Conditions (2006).

Parameters for which there are no standards were not evaluated; however, phosphorus is discussed because of the existing downstream conditions. Chatfield Reservoir is downstream of the confluence of the North Fork South Platte River and South Platte River and has a specific regulation governing its watershed. Regulation No. 73, Chatfield Reservoir Control Regulation, effective January 30, 2006 (CDPHE 2009) addresses phosphorus loading. The upper South Platte River Watershed is allocated a loading of 17,930 pounds per year, which includes 88 pounds per year from Summit County for potential discharge of tertiary treated wastewater directly to Roberts Tunnel. Water quality data in Table 3.2-19 shows phosphorus concentrations downstream of Roberts Tunnel as half of those upstream, indicating that phosphorus concentrations in Roberts Tunnel as less than upstream concentrations. Dillon Reservoir, which supplies Roberts Tunnel, also has a specific regulation devoted to phosphorus control, Regulation No. 71, Dillon Reservoir Control Regulation, effective May 30, 2007 (CDPHE 2007b). This regulation sets a phosphorus standard for Dillon Reservoir at 7.4 µg/L and also lists maximum amounts of phosphorus to be discharged by WWTP. The PACSM results indicate that while there are significant changes in monthly average flows through Roberts Tunnel for all conditions (average, wet, and dry years), for Full Use with a Project Alternative with RFFAs (2032) conditions, the yearly change in flow through Roberts Tunnel would be minimal, ranging from -1 to 5%. Therefore, the annual loading of phosphorus to Chatfield Reservoir would change minimally as a result of changes in deliveries through Roberts Tunnel.

d) Impacts to WWTP Dischargers

No permitted wastewater dischargers are present in the North Fork South Platte River. There would be no impact from changes in flow through Roberts Tunnel.

Conclusions on Potential Changes in Water Quality on North Fork South Platte River

The following summarizes potential changes in water quality in the North Fork South Platte River as a result in changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032) conditions:

- Copper concentrations are anticipated to decrease during periods in which flow increases through Roberts Tunnel, and increase during periods in which flow through Roberts Tunnel decreases. It is not known if copper concentrations would exceed the regulatory standard as hardness concentrations would also change with changes in tunnel deliveries.
- Concentrations of boron, *E. Coli*, dissolved iron, dissolved manganese, dissolved nickel, and dissolved uranium would not change significantly.
- No impact is anticipated with regard to changes in concentration of drinking water parameters.
- Changes in percent source water (native flows versus Roberts Tunnel deliveries) would not be anticipated to cause water quality changes with the exception of copper as noted above.
- There are no WWTP discharges on the North Fork South Platte River and therefore there are no impacts.

South Platte River

For purposes of water quality analysis, the South Platte River was divided into four sections based on the available data from gage stations. The following four sections of the South Platte River are further discussed:

a) Antero Reservoir to the Confluence of the North Fork South Platte River

b) The Confluence of the North Fork South Platte River to Chatfield Reservoir

c) Chatfield Reservoir to the Denver Gage

d) The Denver Gage to Henderson Gage

Each of these potential water quality impacts are discussed in detail below.

a) Antero Reservoir to the Confluence of the North Fork South Platte River

Potential cumulative impacts related to water quality between Antero Reservoir and the North Fork South Platte River would occur from changes in reservoir releases. There are no drinking water providers or permitted wastewater dischargers operating on this segment of the South Platte River, therefore potential water quality changes are not discussed for these uses.

Upstream of the North Fork South Platte River, river flow is determined by releases from Antero, Eleven Mile Canyon, and Cheesman reservoirs. These three reservoirs are on-stream and owned by Denver Water. Under Current Conditions (2006), reservoir water quality would have no significant change, therefore changes in releases would not be expected to change water quality immediately downstream. A change could occur with differing tributary contributions to the mainstem. Conditions exist in which releases from Antero Reservoir would change considerably between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032). Additionally, certain conditions could occur in which releases from Cheesman Reservoir would change between Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032).

The South Fork South Platte River below Antero Reservoir is on the Monitoring and Evaluation List for Aquatic Life Use (CDPHE 2012a). A discussion of the Aquatic Life Use listing is presented in Section 3.11.

Water quality is expected to remain similar to Current Conditions in this segment of the South Platte River under Full Use with a Project Alternative with RFFAs (2032) conditions.

b) The Confluence of the North Fork South Platte River to Chatfield Reservoir

No permitted wastewater dischargers exist on this segment of the South Platte River, therefore, potential water quality changes or impacts to NPDES permits are not discussed. Potential impacts on this segment are listed below.

1) **Water Quality from Upstream of the Confluence with the North Fork South Platte River**
2) **Water Quality in the North Fork South Platte River**
3) **Water Quality from Outlet of Cheesman Reservoir to Fourmile Creek**
4) **Water Quality in Strontia Springs Reservoir**
5) **Water Quality in Chatfield Reservoir**
6) **Impacts to Drinking Water Providers**

Each of these potential water quality impacts is discussed below:

1) Water Quality from Upstream of the Confluence with the North Fork South Platte River

Water quality upstream of the confluence with the North Fork South Platte River would have little change, therefore no alternations are anticipated in this segment resulting from upstream changes.

2) Water Quality in the North Fork South Platte River

The water quality in the North Fork South Platte River has an anticipated change due to changes in Roberts Tunnel deliveries. The following discussion is based on information in the previous subsection on the North Fork South Platte River, as well as information in Table 3.2-20 on water quality downstream of the North Fork South Platte River. Project water quality changes would include changes in concentrations of copper, iron, and nickel as discussed below.

- **Copper** – The 85th percentile concentration of copper in the South Platte River was below detection limits. Therefore, downstream of the confluence, copper concentration would not likely exceed the stream standard of 6.8 µg/L because of the inherent dilution from the South Platte River. However, anti-degradation criteria would cause a change if concentrations increased more than 1.02 µg/L. As with the North Fork South Platte River, during periods of greater water deliveries (versus Current Conditions [2006]), water quality in the North Fork South Platte River would see reduced concentrations of copper. This situation would likely continue resulting in below-detection-limit concentrations in the South Platte River.
- **Iron** – The 85th percentile of iron in the South Platte River (0.1 mg/L) was similar to that in the North Fork South Platte River downstream of Roberts Tunnel. Therefore, reductions in deliveries under Full Use with a Project Alternative with RFFAs (2032) conditions as compared to Current Conditions (2006) would likely result in increased concentrations of iron, although an increase of 15% or greater is undetermined. Periods of greater deliveries through Roberts Tunnel as compared to Current Conditions (2006) would likely result in slight decreases of concentrations of iron. It is unlikely that the stream standard would be exceeded.
- **Nickel** – The 85th percentile concentration of nickel (1.4 µg/L) in the South Platte River was less than the concentration downstream of Roberts Tunnel and less than the stream standard (39 µg/L). A reduction in water delivery through Roberts Tunnel under Current Conditions (2006) would likely result in increased concentrations of nickel. Concentrations would remain less than the stream standard and assimilative capacity would likely increase less than 15%. Periods of greater deliveries through Roberts Tunnel compared to Current Conditions (2006) would likely result in decreases in the concentration of nickel in the North Fork South Platte and the South Platte rivers downstream of the confluence.

3) Water Quality from Outlet of Cheesman Reservoir to Fourmile Creek

The South Platte River from the outlet of Cheesman Reservoir to the confluence with Fourmile Creek is listed on the Monitoring and Evaluation List for Aquatic Life Use (CDPHE 2012a). A discussion of the Aquatic Life Use listing and potential impacts related to the Proposed Action with RFFAs are presented in Section 4.6.11.

4) Water Quality in Strontia Springs Reservoir

Water quality in Strontia Springs Reservoir is dependent on incoming flow and residence time. Using data from the Waterton Canyon gage, PACSM results indicate that changes in flow released from Strontia Springs Reservoir to Chatfield Reservoir occur under a number of conditions. Strontia Springs has a relatively short residence time under Current Conditions (2006), and short residence time would continue under Full Use with a Project Alternative with RFFAs (2032). Therefore, changes in water quality downstream are primarily contingent on the upstream water quality. As noted above, deliveries from Roberts Tunnel could alter concentrations of copper, iron, and nickel. These concentrations would likely remain within regulatory standards and therefore anticipated impacts to Strontia Springs Reservoir would be negligible.

5) Water Quality in Chatfield Reservoir

Water quality in Chatfield Reservoir is dependent on upstream water quality in Plum Creek, reservoir related factors such as recreation and internal nutrient loading, and upstream water quality in the South Platte River. Water quality in Plum Creek contains WWTP discharge and urban stormwater runoff (CDPHE Regulation 73 [CDPHE 2009]), and has the greatest impact on water quality in Chatfield Reservoir. As discussed above, upstream water quality changes in the South Platte River are not expected to be significant. The combination of impacts from Plum Creek and internal nutrient loading indicate little change would be expected from the Proposed Action with RFFAs.

6) Impacts to Drinking Water Providers

Denver and Aurora receive water from Strontia Springs Reservoir. Reservoir water quality would be expected to remain within regulatory standards and not change significantly. Therefore, existing treatment processes would not need enhancement to meet current drinking water regulations. Impacts to drinking water providers would be minimal or nonexistent.

Conclusion for South Platte River from North Fork South Platte River to Chatfield Reservoir

Little to no potential change in water quality would occur on this section of the South Platte River as a result of changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032).

c) Chatfield Reservoir to the Denver Gage

The South Platte River downstream of Chatfield Reservoir is highly regulated and contains numerous withdrawals. Two major municipal wastewater treatment discharges are located on this section of the river; Centennial Water and Sanitation District (CWSD) and the Littleton-Englewood (Bi-City) WWTP. The water quality in the South Platte River below Chatfield Reservoir to the Denver gage is primarily influenced by the following factors:

1) WWTP Discharges from the CWSD and the Bi-City WWTP

2) Water Quality in Chatfield Reservoir

3) Tributary Flow from Bear Creek

4) Possible Impacts from Groundwater Return Flows

5) Impacts to Drinking Water Providers

Each of these potential water quality impacts are discussed in detail below.

1) WWTP Discharges from the CWSD and the Bi-City WWTP

WWTP discharges would increase with increasing population growth. Additionally, stream flows are projected to change per the PACSM. Two methods were used to determine potential impacts related to WWTPs. The first was to estimate the acute and chronic low flow using the CDPHE modified version of DFLOW (Pierce 2010). The second was to estimate the percentage of the river that is wastewater effluent (on a monthly basis) for both Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032).

Using the modeled flow at PACSM Node 51290 for Current Conditions (2006) and Full Use with a Project Alternative with RFFAs (2032), the calculated acute and chronic low flow downstream of Chatfield Reservoir was 0.0 cfs. Therefore, there are no anticipated changes to WWTP NPDES permits as a result of the Project with RFFAs.

2) Water Quality in Chatfield Reservoir

The South Platte River throughout Denver and downstream of Chatfield Reservoir is heavily influenced by WWTP discharges. The PACSM results indicate monthly average low flows of about 8.6 cfs (approximately 5.56 mgd) downstream of Chatfield under Current Conditions (2006). Current permitted capacity for the CWSD is 8.5 mgd and 36 mgd for the Bi-City WWTP (EPA 2010a). Under Current Conditions (2006), the current permitted discharges comprise about 55% of the flow downstream of the CWSD and 86% of the flow downstream of the Bi-City WWTP.

Using the CDPHE method for calculating low flow, under Current Conditions (2006) the estimated acute and chronic low flows of Chatfield releases was 0.0 cfs. Therefore, under Current Conditions (2006), the river could be 100% wastewater effluent (relative to Chatfield releases). Full Use with a Project Alternative with RFFAs (2032) conditions were also projected to have a calculated acute and chronic low flow of 0.0 cfs for Chatfield releases. Therefore, there would be no anticipated change in permits as a result of future Full Use with a Project Alternative with RFFAs (2032).

A potential change could occur in the volume of the river comprised of wastewater effluent on either a monthly or an annual basis. Both daily flows and annual flows were evaluated. Table 4.6.2-23 shows the number of days the South Platte River is effluent only with respect to releases from Chatfield Reservoir for two flow conditions. Daily flows indicate change in both directions.

Table 4.6.2-23
South Platte River Downstream of Chatfield, Changes in PACSM Predicted Low Flows

Parameter	Current Conditions (2006)	Full Use with a Project Alternative with RFFAs (2032)
Number of days at 0 cfs	2,101	2,055
Number of days less than 8.6 cfs	5,495	5,979

As indicated Table 4.6.2-23, for conditions when no releases from Chatfield Reservoir occur, the number of days in which the river is 100% effluent decrease about 2% under Full Use with a Project Alternative with RFFAs (2032) as compared to Current Conditions (2006). For conditions when releases at Chatfield Reservoir are low (less than 8.6 cfs from PACSM analysis of monthly average low flows) the number of days in which the river flow is less than 100% effluent increases about 9%.

To evaluate these changes, flow was examined on an annual basis as some months show an increase in the releases from Chatfield Reservoir while some show a decrease. Table 4.6.2-24 summarizes the results for this evaluation, completed for each condition (average, dry, and wet). The following lists the assumptions used for the evaluation:

- Flow from the CWSD increases between 2007 and 2030 at a rate proportional to estimated population growth in Douglas County (DOLA 2010).
- Flow from the Bi-City WWTP increases through 2020 per the Denver Regional Council of Governments projections. From 2020 to 2030 plant flow would increase at a rate proportional to population growth for Jefferson County (DOLA 2010).
- The current percentage of the river that is wastewater effluent was estimated using 80% of current permitted capacity
- Existing flows downstream of Chatfield Reservoir were estimated using PACSM at Node 51290.
- The Moffat Project with RFFAs would not affect Bear Creek, so any influence (i.e., increase in flow) from Bear Creek as well as additional wastewater plant effluent discharged into Bear Creek was not evaluated in the EIS.

As shown in Table 4.6.2-24, an annual increase was projected for the percent of the river that would be wastewater effluent. However, because the NPDES permits for both WWTPs were written under the Current Conditions of no release of water from Chatfield Reservoir, there would be no significant impact anticipated. With some projected circumstances, the percent of the river that would be wastewater effluent would decrease, specifically during months in which releases from Chatfield Reservoir increase. Also, as noted above, fewer days are projected to occur when Chatfield Reservoir has no water releases.

Table 4.6.2-24
Estimated Changes in Percent Wastewater Effluent Caused by Changes in Releases from Chatfield Reservoir (Using 2030 Estimated Wastewater Effluent Discharges)

	Conditions		
	Average Year	**Dry Year**	**Wet Year**
Downstream of CWSD Wastewater Treatment Plant (WWTP)			
Wastewater in 2030 under Existing Flow Conditions for Chatfield Releases (% of Total Flow)	11	40	4.0
Wastewater in 2030 under Full Use with a Project Alternative with RFFAs (2032) Conditions for Chatfield Releases (% of Total Flow)	12	42	4.3
Change Between Existing and Full Use with a Project Alternative with RFFAs (2032) Conditions for Chatfield Releases (%)	12.5	4.1	5.8
Downstream of Littleton-Englewood (Bi-City) WWTP			
Wastewater in 2030 under Existing Flow Conditions (% of Total Flow)	35	75	15
Wastewater in 2030 under Full Use with a Project Alternative with RFFAs (2032) Conditions for Chatfield Releases (% of Total Flow)	38	76	16
Change Between Existing and Full Use with a Project Alternative with RFFAs (2032) Conditions for Chatfield Releases (%)	8.9	1.7	5.1

3) Tributary Flow from Bear Creek

Water quality may change as a result of change in flows from tributaries. Bear Creek is the largest tributary in this stream segment and is the focus of this discussion. Current data for Bear Creek water quality were not found in either the USGS system or EPA STORET websites; however, the Bear Creek Watershed Group has performed routine monitoring in recent years. This monitoring (as shown on their website) does not extend substantially past Bear Creek Reservoir and would not represent the potential urban influences on the lower reaches. To compensate, information on the South Platte River, both upstream and downstream of Bear Creek was used. As noted in Chapter 3, a number of constituents that indicate influence from Bear Creek on the South Platte River were observed. Bear Creek is highly influenced by wastewater discharges and urbanization, similar to the South Platte River. Most parameters were well within stream standards posing little impact from a change in Bear Creek flow percentage downstream of Bear Creek. However, parameters in exceedance of stream standards are discussed further.

Fecal coliform was greater than the standard at the downstream site. Bear Creek is on the Section 303(d) List for this constituent, and due to a high priority listing Bear Creek would likely have a TMDL developed for fecal coliform in the near future. The purpose of a TMDL is to identify the causes of impairment and develop solutions. Therefore, issues on Bear Creek have high likelihood of being resolved by the time the Moffat Project would be online and water demand increased to the levels of Full Use with a Project Alternative (2032). Bear Creek is a highly regulated stream with numerous withdrawals and wastewater discharges, and a major reservoir. Because both Bear Creek and the South Platte River are highly regulated with strong urbanization influences, no impact is projected for changing the percent of source waters downstream of Bear Creek.

4) Possible Impacts from Groundwater Return Flows

The PACSM analysis was conducted on flow changes in the South Platte River between Chatfield Reservoir and the Denver gage. Results from these two sampling sites indicate increased flows from both wastewater effluent and groundwater sources. Shallow groundwater containing lower water quality could negatively impact the river through return flows. However, this is not suspected for the following reasons:

- Using the EPA's Envirofacts website (EPA 2010d), no superfund sites were identified for this reach of river.
- Nitrate sampling at the two sample sites indicated a decrease at the downstream site, indicating little influence from agriculture in this area.

Changes were also observed for a number of parameters shown in Section 3.2. The sources of these changes are unknown, therefore an increase in groundwater return flows could cause an impact. These potential impacts are not likely to be significant as WWTP discharges would contribute the greatest increase in return flows.

5) Impacts to Drinking Water Providers

The City of Englewood is the only water provider with an intake along this portion of the South Platte River. This intake is located between the sampling sites. Sampling at both sites reveals sodium levels greater than the EPA's advisory level of 20 mg/L. Sodium is on the contaminant candidate list in part because EPA believes this guidance level needs updating (EPA 2010c). Although sodium exceeds the current advisory level, there is likely no health concern with the levels found at both sampling sites. TDS levels were found to be greater than the EPA's secondary limit at both sampling sites. Water with TDS levels higher than advisory level is considered safe but may have aesthetic concerns including corrosion and taste issues. Changes in flows from Chatfield Reservoir are not likely to change either of these parameters and therefore no cumulative impacts to this drinking water provider are anticipated.

Conclusions for South Platte River from Chatfield Reservoir to the Denver Gage

The following summarizes the potential changes in water quality in this section of the South Platte River as a result in changes from Current Conditions (2006) to Full Use with a Project Alternative with RFFAs (2032) conditions:

- No changes are anticipated to WWTP discharge permits
- No impact is projected for influences from changes in flow between Chatfield Reservoir and Bear Creek

d) Denver Gage to Henderson Gage

The South Platte River from the Denver gage to Henderson gage is highly regulated containing numerous withdrawals. Potential impacts caused by changes in flows under Full Use with a Project Alternative with RFFAs (2032) conditions include:

1) **Potential Changes to Water Quality Caused by Changes in WWTP and Stormwater Discharges (both of these conditions are outside any influence of Full Use with a Project Alternative with RFFAs [2032] conditions)**
2) **Possible Changes in Water Quality Caused by Changes in Groundwater Return Flows**

Each of these potential water quality impacts are discussed below:

1) Possible Changes to Water Quality Caused by Changes in WWTP and Stormwater Discharges

From the Burlington Ditch to the confluence with Big Dry Creek, the South Platte River is designated Use Protected. Therefore, when calculating loading for discharge permits, the CDPHE determines if the total concentration of parameters of interest would remain below stream standards; the criteria of using only 15% of available capacity is not applicable for Use Protected segments.

For months in which river flow increases, return flows are the source. To estimate the impact of return flows from WWTP discharge, the following assumptions were used:

- It is assumed that WWTP would not discharge more than 80% of the permitted capacity. State regulations provide for design of a plant expansion when flow reaches 80% of capacity and that construction should start prior to reaching 95% of capacity. Using percent provides for a more conservative (lower) estimate of the percentage of wastewater effluent allowed under current permit conditions as the permits are written for 100% of the permitted capacity. In addition, most WWTP entities have construction completed prior to reaching the 95% flow threshold.

- The current percentage of the river that is wastewater effluent is estimated using 80% of current permitted capacity. This provides for a conservative (lower) estimate of the percentage of wastewater effluent allowed when determining the percent change that is significant.

The Metro WWTP Robert W. Hite Treatment Facility's current permitted capacity is 227 mgd, or about 351 cfs, (EPA 2010a). Assuming 351 cfs as the maximum discharge under Current Conditions (2006), 80% permitted capacity is 281 cfs. The chronic low flow for the South Platte River at 64th Street (upstream of the Metro WWTP discharge) is estimated at 7 cfs. Therefore, just downstream of the Metro WWTP's discharge, the South Platte River would contain up to 97.5% wastewater effluent under Current Conditions (2006). Per earlier discussions, an increase of 15% or more would be considered a change; however, an increase of 15% is not possible. Therefore, there would be no change caused by an increasing percentage of WWTP discharge, and it is anticipated that no cumulative impacts would result from Full Use with a Project Alternative with RFFAs (2032) conditions. Because the potential for the river to contain more than 95% wastewater effluent already occurs, no changes to permit limits are anticipated.

2) Possible Changes in Water Quality Caused by Changes in Groundwater Return Flows

Groundwater influences on surface water quality would be primarily the result of existing groundwater quality and non-point sources. Using information in Table 3.2-23, the following parameters at 64th Avenue are of interest due to steam standard exceedances:

- **Cadmium, dissolved** – It is likely that exceeding the stream standard is the result of cadmium in the groundwater plume from the Globe Superfund site near Vasquez Boulevard and Interstate 70 (I-70) (CDPHE 2006). As such, increased groundwater flow from other areas would most likely reduce cadmium concentrations from dilution effects. Increases in groundwater flow caused by the Full Use with a Project Alternative with RFFAs (2032) conditions would occur primarily from lawn irrigation and would not affect the plume from the Globe Superfund site.
- **Chromium, dissolved** – The stream standard listed Table 3.2-23 is for Chromium VI. The data are reported as total dissolved chromium, with no indication of the distribution of the chromium species. Of note is that the stream standard for Chromium III is calculated to be 143 µg/L per the Regulation No. 38 TVS equation (CDPHE 2011b). The source of chromium is unknown but is likely from industrial sources. Although it is unknown whether chromium exceeds the stream standard, it is likely that it would not. The predicted increase in groundwater flow would come from residential areas and would not be expected to increase the concentration of chromium.
- ***E. Coli* and fecal coliform** – As mentioned earlier, a TMDL assessment for *E. Coli* is in place for the majority of this river segment (CDPHE 2006). The TMDL assessment does not indicate groundwater as a significant source for *E. Coli*. Therefore, increases in groundwater flow are not likely to increase *E. Coli* or fecal coliform counts and no impact to those counts is anticipated.

Sulfate exceeds secondary drinking water standards as shown in Table 3.2-23, and can only be removed through AWTP processes such as reverse osmosis. The source of the sulfate is most likely a groundwater plume associated with the General Chemical site located near the South Platte River and Bayaud Avenue (DDEH 2006). Therefore, changes in return flows are likely to have negligible impacts on sulfate concentrations.

Conclusion for South Platte River Denver Gage to Henderson

Based on only minor changes in water quality, cumulative impacts to water users, including potable providers, are not anticipated under the Proposed Action with RFFAs.

Stream Segments Outside the Project Area Listed in Regulation 93 or Having a TMDL

As noted in Section 3.2, a number of stream segments downstream of the Project area have been identified as impaired or having potential impairment. These stream segments are examined below to determine if the Proposed Action with RFFAs would contribute to or causes the impairment or potential impairment.

Stream segments that are listed in Regulation 93 have not had the cause of impairment (or potential impairment) identified and, in some cases, have been on the list of impaired stream segments for over two decades (Hillegas 2010). In the absence of knowledge as to the cause of impairment or potential impairment, evaluation of potential impacts to these segments that might occur as a result of the Proposed Action with RFFAs was based on the following criteria:

- Would loading to the impaired or potentially impaired segments outside the Project area be affected as a result the Proposed Action with RFFAs?
- Would the Proposed Action with RFFAs result in reduction in dilution flows in impaired or potentially impaired segments outside the Project area?

Colorado River Basin

The Humphrey Backwater portion of the Rapid Creek to Gunnison River Segment of the lower Colorado River is on the Section 303(d) List for selenium (CDPHE 2012a). Selenium is a micronutrient and required for most cellular functions. In high doses, selenium exhibits toxicity and can be harmful to aquatic ecosystems. The Reclamation report (Reclamation 2003) states that the source of selenium causing impairment in the Humphrey's Backwater area is primarily irrigation drainage that enters the site through Lewis Wash (a tributary to the Colorado River) and the Grand Junction Drainage District's GJ3 Drain. The Reclamation report suggests that the Colorado River is not a major contributor of Selenium to the Humphrey's Backwater area, and that Colorado River flows are being used for dilution and flushing of the site.

The lower Colorado River from the confluence of the Roaring Fork to the confluence with the Gunnison River is on the Monitoring and Evaluation List for sediment (CDPHE 2012a). These segments were first identified in the Colorado Nonpoint Assessment report published by the WQCD in November 1989 (Hillegas 2010). The Division does not currently have a protocol or standards for assessing large rivers for sediment attainment, and the cause(s) of the possible impairment remain unknown. Therefore it is not currently possible to quantify the effects of upstream flow reductions and resulting regulatory compliance actions. Given the relatively low reductions in flow (i.e., less than 10%), and the relatively short duration of the flow reductions (i.e., two to three months in average years), it is not anticipated that the Proposed Action with RFFAs would contribute to the sediment impairment on the lower Colorado River.

South Platte River Basin

The South Platte River from Burlington Ditch to Big Dry Creek is on the Section 303(d) List for *E. Coli* (CDPHE 2012a), and has TMDLs for DO and cadmium (CDPHE 2012b). These are discussed above because a portion of the segment is in the Project area. Downstream of the Project area, three parameters of are of concern: selenium, manganese, and *E Coli*. These parameters are addressed in the following paragraphs.

The South Platte River from the confluence with St. Vrain Creek (north of Platteville) to the State line is listed in Regulation 93 on the Section 303(d) List for selenium (CDPHE 2012a). The source of the selenium downstream of St. Vrain Creek is unknown (Hillegas 2010). Upstream data was used to determine if the source of selenium was within the Project area (upstream of Henderson). A sampling station at 124th Avenue (Henderson) indicates no data points greater than the standard. Therefore, upstream flows do not appear to be contributing to selenium concentrations. The most likely impact from the Proposed Action with RFFAs would be changes in dilution flows. Modeled flows at Henderson were examined to estimate the magnitude of potential effects on dilution flows in this segment. Annual flows at Henderson were very similar under Full Use with a Project Alternative with RFFAs (2032) as compared to Current Conditions (2006), with slightly less flow (2% or less) during average and wet years and slightly more flow (about 5%) during dry years. During April of average and wet years, predicted flows decreased more than 10%. This segment of the river is highly regulated with numerous diversions and return flows, including (but not limited to) the Brighton Ditch, the Platteville Ditch, City of Brighton return flows, and Fulton Ditch return flows. As evidence of the highly regulated nature of this river segment, the river has a dry-up point upstream of the confluence with St. Vrain Creek (CDWR 2008a). Because of the regulated nature of this river segment, upstream flows have little relation to the downstream flows and the upstream flows provide consistent dilution. It is not anticipated that flow changes resulting from the Proposed Action with RFFAs would cause or contribute to exceeding selenium standards downstream of St. Vrain Creek.

The South Platte River from the Weld/Morgan county line to the State line is listed in Regulation 93 on the Section 303(d) List for manganese (CDPHE 2012a). The ambient concentration of manganese is below the stream standard for aquatic life, but exceeds the secondary drinking water standard of 50 µg/L. The secondary drinking water standard for manganese is set for aesthetic purposes. Manganese is readily removed by conventional water treatment processes. As discussed in Section 3.2, manganese concentrations are greater than the secondary drinking water level as far upstream as 64th Avenue. As noted above, flows in the South Platte River are highly regulated. Changes to manganese levels caused by Full Use with a Project Alternative with RFFAs (2032) are not anticipated at the Weld/Morgan County line due to the numerous withdrawals and returns discussed above.

The South Platte River from Big Dry Creek to St. Vrain Creek is listed in Regulation 93 on the Section 303(d) List for *E. Coli* (CDPHE 2012a). Note that the segment just upstream is also listed for *E. Coli* as discussed above. Sources of *E. Coli* in this segment are not known (Hillegas 2010). However, as noted previously, *E. Coli* is not a conservative parameter and likely sources are stormwater and treated wastewater effluent. It is not anticipated that the Proposed Action with RFFAs would influence *E. Coli* levels in this segment of the river.

Boulder Creek Basin

CDPHE has developed a TMDL for ammonia for the mainstem of Boulder Creek downstream of South Boulder Creek (CDPHE 2012b). This TMDL indicated that the source of ammonia was point source discharges, specifically treated wastewater effluent from WWTPs. This TMDL also indicated that more stringent permit limits on WWTP dischargers would allow the stream to be in compliance for ammonia. South Boulder Creek is highly regulated from Gross Reservoir to its mouth, with numerous canals that withdraw water. The CDPHE version of DFLOW was used to estimate acute and chronic low flows at Eldorado Springs. These low flows are significantly higher than the estimated acute and chronic low flows noted in the TMDL for South Boulder Creek. Therefore, is not anticipated that flow changes at Eldorado Springs would have an impact on ammonia levels in Boulder Creek. No impact to this TMDL is anticipated as a result of the Full Use with a Project Alternative with RFFAs (2032).

Boulder Creek downstream of South Boulder Creek is also on the Monitoring and Evaluation List for cadmium and arsenic. Additionally, this stream segment is listed on the Section 303(d) List for Aquatic Life Use and *E. Coli*. Based on the relative flows at Eldorado Springs and farther downstream presented in the preceding paragraph, it is not anticipated that Full Use with a Project Alternative with RFFAs (2032) conditions would cause or contribute to an impairment or potential impairment of Boulder Creek.

Boulder Creek from 107th Street to the Confluence with Coal Creek is provisionally listed on the Section 303(d) List for Aquatic Life Use, and Boulder Creek from Coal Creek to St. Vrain Creek is on the Monitoring and Evaluation List for Aquatic Life Use (CDPHE 2012a). A discussion of the Aquatic Life Use listings and potential impacts related to the Proposed Action with RFFAs are presented in Section 4.6.11.

Conclusion for South Boulder Creek Impacts

No significant cumulative impacts to the stream segments listed in Regulation 93 downstream of the Project area are anticipated as a result of the Proposed Action with RFFAs.

4.6.2.2 Alternative 1c with Reasonably Foreseeable Future Actions

4.6.2.2.1 Reservoir Water Quality

Williams Fork Reservoir

Changes to Williams Fork Reservoir water quality would be similar to the Proposed Action with RFFAs.

Dillon Reservoir

Changes to Dillon Reservoir water quality would be similar to the Proposed Action with RFFAs.

Wolford Mountain Reservoir

Changes in water quality would be the same as the Proposed Action with RFFAs.

Gross Reservoir

The potential impacts to reservoir water quality under Alternative 1c would be similar to those described for the Proposed Action with RFFAs. The reservoir size would be smaller under Alternative 1c, as compared to the Proposed Action, and residence times would also be less. Due to the smaller reservoir size, as compared to the Proposed Action, less land would be inundated, possibly resulting in reduced short-term water quality impacts of increased organic carbon and nutrients in the water column, and mercury in fish tissue. Cumulative impacts to water quality in Gross Reservoir under Alternative 1c are expected to be minor to moderate for the short term and negligible for the long term.

Leyden Gulch Reservoir

A large portion of the water that would be stored in Leyden Gulch Reservoir would be diverted during average and wet years when the inflow may have slightly elevated levels of TOC and turbidity. This diversion could affect reservoir water quality. Leyden Gulch Reservoir would have a greater water quality impact from storing additional water from Gross Reservoir than if that water were to remain in Gross Reservoir under the Proposed Action with RFFAs and fluctuate in elevation as needed. Leyden Gulch Reservoir would likely not stratify in summer and would have sufficient DO at most or all depths to sustain aquatic organisms. The reservoir may be operated near capacity for extended periods. Minor variances in water quality inflow in South Boulder Creek could have multi-year impacts. Water quality data are not available to fully evaluate this impact; therefore, impacts and their magnitudes are not known. Cumulative impacts to water quality in Leyden Gulch Reservoir (as compared to current water quality in Gross Reservoir) would be minor.

Antero Reservoir/Eleven Mile Canyon Reservoir/Cheesman Reservoir/Strontia Springs Reservoir/Chatfield Reservoir

Changes in water quality under Alternative 1c would be similar to the Proposed Action with RFFAs.

4.6.2.2.2 River Segments

Changes in water quality for all stream segments under Alternative 1c would be similar to the Proposed Action with RFFAs. Impacts to South Boulder Creek of reduced outflow temperatures from Gross Reservoir would be expected to be slightly less than those predicted under the Proposed Action, due to the slightly smaller reservoir size and shorter residence times. Aquatic life effects associated with water temperatures in South Boulder Creek are discussed in Section 4.6.11.

Stream Segments Outside the Project Areas with Section 303(d) or Monitoring and Evaluation Listing

As noted above, changes would be similar to the Proposed Action with RFFAs within the Project area. Therefore, as these stream segments are downstream of the Project area, any changes in these stream segments would be similar to those for the Proposed Action with RFFAs.

4.6.2.3 Alternative 8a with Reasonably Foreseeable Future Actions

4.6.2.3.1 Reservoir Water Quality

Williams Fork Reservoir

Changes in water quality under 8a would be similar to the Proposed Action with RFFAs.

Dillon Reservoir

Changes in water quality under 8a would be similar to the Proposed Action with RFFAs.

Wolford Mountain Reservoir

Changes in reservoir operations, evaporation, contents, elevations, and water quality under Alternative 8a would be the same as the Proposed Action with RFFAs.

Gross Reservoir

The potential impacts to reservoir water quality under Alternative 8a would be similar to those described for the Proposed Action with RFFAs. The reservoir size would be slightly smaller under Alternative 8a, as compared to the Proposed Action, and residence times would also be shorter. Due to the smaller reservoir size, as compared to the Proposed Action, less land would be inundated, possibly resulting in slightly reduced short-term water quality impacts of increased organic carbon and nutrients in the water column, and mercury in fish tissue. Cumulative impacts to water quality in Gross Reservoir under Alternative 8a are expected be minor to moderate for the short term and negligible for the long term.

4.6.2.3.2 River Segments

Changes in water quality for all river segments under Alternative 8a would be similar to the Proposed Action with RFFAs. Impacts to South Boulder Creek of reduced outflow temperatures from Gross Reservoir would be expected to be slightly less than those predicted for the Proposed Action, due to the slightly smaller reservoir size and shorter residence times. Aquatic life effects associated with water temperatures in South Boulder Creek are discussed in Section 4.6.11.

Possible impacts to the Moffat WTP would be dependent on the extent of water treatment from the gravel pit storage as described in Alternative 8a.

This water is treated by an AWTP process prior to being conveyed to the South Boulder Diversion Canal and just before the water enters Ralston Reservoir. The AWTP treated water should not be adding significant amounts of nutrients (ammonia and phosphorus) to

Ralston Reservoir, which would degrade the reservoir water quality through algae growth. The AWTP processes use reverse osmosis membranes and breakpoint chlorination for the removal of nutrients. The AWTP processes are expected to remove phosphorus to less than 0.05 mg/L and nitrate to less than 0.01 mg/L. If nitrate is removed, ammonia is also removed, as is the likelihood that algae would grow in the reservoir. A potential for nutrients getting into Ralston Reservoir would exist if the AWTP processes are not able to achieve the expected removal efficiencies.

Stream Segments Outside the Project Areas with Section 303(d) or Monitoring and Evaluation Listing

As noted earlier, changes would be similar to the Proposed Action with RFFAs within the Project area. Therefore, as these stream segments are downstream of the Project area, any changes in these stream segments would be similar to those for the Proposed Action with RFFAs.

4.6.2.4 Alternative 10a with Reasonably Foreseeable Future Actions

Changes in the water quality of river segments and reservoirs would be the same as described under Alternative 8a, which would also be similar to the Proposed Action with RFFAs. CDPHE permit conditions preclude degradation of groundwater quality from well injection.

4.6.2.5 Alternative 13a with Reasonably Foreseeable Future Actions

Changes in the water quality of river segments and reservoirs would be the same as described under Alternative 8a, which would also be similar to the Proposed Action with RFFAs.

4.6.2.6 No Action Alternative with Reasonably Foreseeable Future Actions

In general, reservoir operation would be different under the No Action Alternative strategies (Demand Restrictions, Depletion of the Strategic Water Reserve and a Combination) than under the action alternatives.

Williams Fork Reservoir

Williams Fork Reservoir would be operated similarly to the Proposed Action with RFFAs. Therefore, changes in the reservoir and downstream of the reservoir would be similar to those described under the Proposed Action with RFFAs.

Dillon Reservoir

Under the No Action Alternative, more water would be released from Dillon Reservoir as compared to the Proposed Action with RFFAs, resulting in greater fluctuations. Given the depth of this reservoir, no significant changes would be anticipated in water quality.

Wolford Mountain Reservoir

Under the No Action Alternative, Wolford Mountain would be operated similar as under the Proposed Action with RFFAs. Therefore, changes would be similar to those described under the Proposed Action with RFFAs.

Gross Reservoir

Gross Reservoir water quality under the No Action Alternative would be anticipated to be similar to Current Conditions (2006) due to similar inflow concentrations and residence times. Annual ranges of water levels would also be similar, though ranges would be slightly greater for the No Action Alternative. Unlike the other alternatives, there would not be a short-term increase in organic carbon and nutrient concentrations in the water column, or mercury concentrations in fish tissue, since no additional areas would be inundated. Cumulative impacts to water quality in Gross Reservoir would be negligible.

Antero Reservoir

The annual changes would be similar to those under the Proposed Action with RFFAs. Changes in water quality would not be anticipated.

Eleven Mile Canyon Reservoir

Water quality within the Eleven Mile Canyon Reservoir would be dependent on either the upstream water quality from the South Platte River, or reservoir changes of operation, evaporation, contents, and water surface elevation. Reductions to reservoir contents would be greater under the No Action Alternative than the action alternatives with RFFAs, but it is unlikely to affect water quality. Therefore, water quality in Eleven Mile Canyon Reservoir would not be expected to change because of operational scenarios associated with the No Action Alternative and, therefore, no impacts would be anticipated.

Cheesman Reservoir

Water quality within the Cheesman Reservoir would be dependent on either the upstream water quality from the South Platte River, or reservoir changes of operation, evaporation, contents, and water surface elevation. Reductions to reservoir contents would be greater under the No Action Alternative than the action alternatives with RFFAs, but it is unlikely to affect water quality. Therefore, water quality in Cheesman Reservoir would not be expected to change because of actions associated with the No Action Alternative.

Strontia Springs Reservoir

Water quality within the Strontia Springs Reservoir would be dependent on either the upstream water quality from the South Platte River, or reservoir changes of operation, evaporation, contents, and water surface elevation. South Platte River water quality changes would be possible with regard to copper, iron, and nickel, but expected to be less because of increased Roberts Tunnel deliveries. The reservoir would operate within the same general water surface elevation range, and therefore water quality changes would not be expected because of operational changes associated with the No Action Alternative.

Chatfield Reservoir

Water quality within Chatfield Reservoir would be dependent on either the upstream water quality from the South Platte River, or reservoir changes of operation, evaporation, contents, and water surface elevation. Annual Roberts Tunnel deliveries would increase more under the No Action Alternative as compared to the Proposed Action with RFFAs (refer to Table H-3.34). Therefore annual loadings of phosphorus to Chatfield Reservoir could be greater than under the Proposed Action with RFFAs. Additional deliveries could result in greater phosphorus loading to Chatfield Reservoir. Note that additional diversions upstream of Chatfield Reservoir would occur under the No Action Alternative. Therefore, changes in phosphorus loadings are dependent on the timing of Roberts Tunnel deliveries, the timing of diversions, and actual phosphorus concentrations which could result in minor cumulative impacts. South Platte River inflow water quality changes are possible with regard to copper, iron, and nickel. The reservoir would operate within the same general water surface elevation range and minor cumulative impacts would be expected from operational changes associated with the No Action Alternative.

4.6.2.6.1 Stream Segments

Fraser River

Flow decreases would generally be less than under the Proposed Action with RFFAs. Therefore, the potential for impacts to water quality would be somewhat less than under the Proposed Action with RFFAs but very similar.

Williams Fork River

The No Action Alternative would result in less water diverted from the four headwater creeks, as compared to the Proposed Action with RFFAs, resulting in greater stream flow throughout the Williams Fork River Basin. Impacts would be similar but less intense as compared to the Proposed Action with RFFAs.

Colorado River Water

Estimated flows under the No Action Alternative would be similar to the Proposed Action with RFFAs. Therefore, changes in water quality would be similar to the Proposed Action with RFFAs.

Muddy Creek

Estimated flows under the No Action Alternative would be similar to the Proposed Action with RFFAs. Therefore, changes in water quality would be similar to the Proposed Action with RFFAs.

Blue River

Flow reductions would be greater under the No Action Alternative under some conditions as compared to Full Use with a Project Alternative with RFFAs (2032). Therefore, impacts related to WWTP discharges would be greater. Two statistics in the daily PACSM data for Node 4250, Dillon Reservoir outflow were reviewed. The first is the number of days where flow is projected to be less than 50 cfs. The number of days would be the same as projected under Full Use with a Project Alternative with RFFAs (2032). The second is acute and chronic low flow using the CDPHE modified DFLOW program (Pierce 2010). Again, the estimated acute and chronic low flows are estimated to be the same as under Full Use with a Project Alternative with RFFAs (2032) conditions.

Tributary influences would be slightly greater under the No Action Alternative as compared to the Full Use with a Project Alternative with RFFAs (2032) from the decreases in releases from Dillon Reservoir.

Other water quality changes are anticipated to be similar to the Proposed Action with RFFAs.

South Boulder Creek

In average and wet years, less water would be diverted through the Moffat Tunnel when comparing the No Action Alternative to the Proposed Action with RFFAs. The described changes under the Proposed Action with RFFAs as a result of dilution from the Moffat Tunnel discharges would be similar but smaller scale under the No Action Alternative with the exception of dilution water for the Moffat Railroad Tunnel NPDES permit. Acute low flow through the Moffat Tunnel under the No Action Alternative is estimated to be zero, identical to Current Conditions (2006) but less than the estimated low flow under Full Use with a Project Alternative with RFFAs (2032). Therefore, less dilution flow would be available for the Moffat Railroad Tunnel Discharge Permit under the No Action Alternative than the Full Use with a Project Alternative with RFFAs (2032) conditions.

Effects on South Boulder Creek related to Gross Reservoir water quality (outflow to South Boulder Creek) are expected to be negligible, since no significant effects are anticipated in the reservoir for the No Action Alternative relative to Current Conditions.

North Fork South Platte River

Deliveries through Roberts Tunnel would be different under the No Action Alternative as compared to the Proposed Action with RFFAs. Except for one month, deliveries would be the same as or greater than Current Conditions (2006). Therefore, the changes in water quality in the North Fork South Platte River would generally be a decrease in parameters of concern discussed above except for uranium. Uranium is expected to still be well within stream standards with increasing deliveries.

Significant differences in flow through Roberts Tunnel would occur when comparing Current Conditions (2006) to the No Action Alternative. Flows through Roberts Tunnel increase under all conditions.

In average years, Roberts Tunnel deliveries increase from 10 to 56% with the greatest increase in June. The annual percentage increase from Roberts Tunnel would be 18% in average years.

In dry years, the percent contribution from Roberts Tunnel increases between 5 and 26%. Annual deliveries would increase under Full Use of the Existing System with the No Action Alternative (2032) with the change in percent contribution from Roberts Tunnel being about 10%.

In wet years, the percent contribution from Roberts Tunnel increases from 9 to 437%, with the greatest increase in July. The annual average percent contribution is 30% greater under Full Use of the Existing System with the No Action Alternative as compared to Current Conditions (2006).

As previously described, water imports from Roberts Tunnel substantially change some water quality parameters. Parameters of concern are copper, iron, nickel, aluminum, and phosphorus. Copper, iron, nickel, and aluminum concentrations would decrease with increasing levels of water from Roberts Tunnel. Therefore, the impact to the North Fork South Platte River for the No Action Alternative would be decreased concentration of parameters that are of concern. Additional phosphorus loads are added to the South Platte River Basin, including Chatfield Reservoir, with increasing deliveries of water from Dillon Reservoir.

South Platte River

Antero Reservoir to North Fork South Platte River

Conditions would be very similar to those described for the Proposed Action with RFFAs, except that releases are projected to be about 3 cfs less. Therefore, as with the Proposed Action with RFFAs, no changes to water quality are anticipated.

North Fork South Platte River to Chatfield Reservoir

With one exception, no significant changes would be anticipated in water quality under the No Action Alternative for either upstream of the confluence with the North Fork South Platte River or the North Fork South Platte River itself. The exception would be additional phosphorus loadings caused by increased annual deliveries through Roberts Tunnel. Downstream of Strontia Springs, water quality would be affected by water quality within the reservoir. As water quality of reservoir inflow is not expected to change, water quality downstream of the reservoir is also not expected to change. Phosphorus loading into Chatfield Reservoir is highly regulated and the minor increase noted above may have an impact; therefore, minor cumulative impacts are anticipated.

Chatfield Reservoir to the Denver Gage

Water quality changes in the South Platte River downstream of the Chatfield Reservoir to the Denver gage under the No Action Alternative would be similar to the Proposed Action with RFFAs.

Denver Gage to Henderson

Only a small change in flow was modeled at the Denver and Henderson gages under the No Action Alternative as compared to the Proposed Action with RFFAs. This is because of the high return flows from the Metro WWTP and return flows via groundwater. The river under Current Conditions (2006) is primarily WWTP discharges and return flows from groundwater. Therefore, the only significant changes to water quality would be observed if significant increases in groundwater flow, significant changes to wastewater treatment (outside of Denver Water's responsibility), or significant increases in fresh water input to the river were to occur. However, the changes in flow are insignificant; therefore, the cumulative impacts to water quality would also be insignificant.

Stream Segments Outside the Project Areas with Section 303(d) or Monitoring and Evaluation Listing

As noted above, changes would be similar to the Proposed Action with RFFAs within the Project area. Therefore, as these stream segments are downstream of the Project area, any changes in these stream segments would be similar to those for the Proposed Action with RFFAs.

4.6.3 Channel Morphology

The affected environment for channel morphology is described for Current Conditions (2006) in Section 3.3. This cumulative impacts analysis evaluates the changes in channel morphology due to flow changes associated with each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs) and past actions. Water-based RFFAs that were considered for the cumulative effects analysis are shown in Table 4.3.1-1. The potential total effects to channel morphology are evaluated against Current Conditions (2006).

Channel morphology would not be impacted by construction activities as Gross Reservoir, Leyden Gulch Reservoir, various conveyance structures (Conduit M, Conduit O, and gravel pit pipelines), the South Platte River Facilities, or the Denver Basin Aquifer Facilities. Thus, cumulative impacts to channel morphology associated with these alternative components were not evaluated.

The following bullets summarize the major evaluations conducted as part of the impact analyses of channel morphology. Methods and conclusions are discussed in more detail in the following sections.

- Predicted impacts to channel morphology were based on a combination of field observations, analysis of historic data, review of relevant studies, flow frequency analysis, numeric modeling, and professional judgment.
- Field observations included detailed assessments of 16 Representative channel sites, evaluation of 32 Reconnaissance sites and inspection of the river system at specific points of interest including areas below diversions.
- Historic data evaluated for this assessment included aerial photos, limited ground photos at selected sites, cross sectional data and U.S. Geological Survey (USGS) gage data records.
- Flow frequency analyses included an evaluation of the changes in the frequency and the time between various flood events and flows needed to initiate mobilization of the stream bed.
- Quantitative modeling including the definition of effective discharge, calculation of the anticipated change in sediment transport capacity and the definition of the point where Phase 2 sediment transport occurs.
- To assess predicted impacts of flow changes on channel morphology, detailed analyses were completed at Representative sampling sites along the Fraser River (3 sites), St. Louis Creek, Ranch Creek, Vasquez Creek, Jim Creek, Williams Fork River (2 sites), Colorado River (2 sites), Blue River, South Boulder Creek (2 sites), and the North Fork South Platte River (2 sites). Given the minor flow changes predicted in the South Platte River, impacts to channel morphology are predicted to be negligible

therefore detailed assessments of morphology were not conducted on the main stem of the South Platte River.

The assessment of channel morphology and the predicted impacts resulting from Project alternatives were determined using a combination of physical evidence and numerical modeling techniques. Analytical techniques presented in this section were also used to assess potential impacts from Full Use of the Existing System to Project alternatives presented in Section 5.3. Current and past aerial photos were analyzed to determine discernable trends in channel widths and stream sinuosity. USGS stream gage information including rating data over the available period of record was examined. Stream cross sectional data obtained from the Fraser River at the time of the Board of Water Commissioners' (Denver Water's) original diversions were obtained and replicated and historic ground photos taken of the river systems were obtained and recreated.

Historic data were compared with Current Conditions (2006) to define changes in the physical stream settings. Trends of widening or narrowing of channels, changes in sinuosity, elevated or lowered stream rating curves, changes in channel cross sections and differences in ground photos were analyzed for indications of channel response to past diversions which would help predict responses to additional flow alterations. This information provides a basis for evaluating future changes that may occur given the potential flow alterations caused by the various Project alternatives and other RFFAs.

All predicted changes in channel morphology were evaluated against the backdrop of natural channel variability. Localized sediment aggradation and degradation are natural stream processes that occur in any channel and should be expected to occur within all of the stream segments evaluated as part of this Environmental Impact Statement (EIS). As an example, deposition of fine sediment occurs in areas with lower velocities and with lower stream gradients. Localized bank instability is also a natural process and is expected to occur at channel bends and in places where bank material is finer and more susceptible to erosion. As described in Section 3.3, this type of natural variability was observed as part of the evaluation of existing channel conditions. Fine sediment deposition was observed in locations such as the Fraser River downstream of Denver Water's diversion, but was also observed in locations such as Vasquez Creek above Denver Water's diversion. Similarly, localized unstable banks were encountered at many locations. However, these unstable banks were generally observed as isolated features within a reach where the overall condition of banks and stream were stable. Observations presented in Section 3.3 suggest that the current stream conditions are typical of a natural system and with minor exceptions, suggest that the current streams throughout the Project area are generally stable with aggradation and degradation within the range of what is expected given natural channel variability.

Available research including assessments completed within the Project area was evaluated and utilized to help formulate components of the quantitative assessment efforts. Numeric modeling was performed to quantify changes to the river system in response to the Project alternatives. Changes in sediment transport capacity, flood flow magnitudes and frequencies, the frequency of flows that disrupt the channel bed and effective discharges were compared.

Localized aggradation, in both time and space, should be expected and is part of the natural channel process. Similarly, localized bank erosion of bed downcutting occurs in natural stream systems and is not a sign of systematic stream instability. Conclusions reached in this EIS focus on whether changes in flows resulting from the various Project alternatives with RFFAs are predicted to result in long-term changes in the stream system that are likely to alter channel morphology. Numeric modeling as well as available physical data was used to inform the interpretation of potential impacts.

4.6.3.1 Methods for Historic Data Assessment

Historic Aerial Photos

Historic aerial photos were utilized as a means to determine whether past diversions or other land use practices have resulted in notable large scale changes to stream morphology. Stream sinuosity (stream length divided by valley length) and stream widths were determined using available aerial photos and compared throughout time in an attempt to identify trends that may be occurring. Significant changes in sinuosity would be a possible indicator of large scale stream responses. A trend of increasing stream width could be an indication of bank erosion whereas a trend of channel narrowing could be an indication of channel deposition and vegetative encroachment.

Aerial photos comparisons were made utilizing the oldest and most recent quality photos available to define changes over the longest available period of record. Stream segments were selected for comparison only if the quality of the photo was sufficient to provide accurate sinuosity and width measurements. Sinuosity measurements were taken by tracking the thread of the channel over the length of the segment evaluated and dividing this length by the straight line distance from the beginning to the end of the segment. Width measurements were taken at distinct locations visible on both photos generally equally spaced along the length of the segment. Width measurements were taken from stream bank to stream bank rather than as the width of the water in an attempt to minimize influences of flows during the date of the photo. The limited areas with quality images for both historic and Current Conditions (2006) limited the areas that would be reasonably compared.

Measurements of sinuosity and channel widths were made utilizing Geographic Information System technology at 20 locations. Measurements were typically made in the vicinity of Representative sites with several additional locations added where photo quality allowed. Locations included stream segments downstream of diversions where past diversions have resulted in decreased flows, stream segments where water deliveries have increased native flows and in control sections where Denver Water’s past diversions have not impacted stream conditions. Maps showing the specific location of each segment and cross sections are provided in Figures H-16.1 to H-16.6 in Appendix H-16. In some locations resolution of the aerial photos made it possible to define channel sinuosity over a longer reach with channel widths only discernable over a portion of the total segment. Segments above diversions were generally limited in length given the limited size and vegetative cover in the upper segments of these streams. Description of the site locations used for aerial photo interpretation, date of the initial and recent photos and measured changes in channel widths are given on Table 4.6.3-1. Sinuosity changes in channel sinuosity are provided in Table 4.6.3-2. Channel widths are taken as the average width of all measured cross sections at an individual site. Sinuosity values are based on the single measurement per segment. Data summarizing all measurements is provided in Tables H-17.1 to H-17.6 in Appendix H-17.

Table 4.6.3-1
Aerial Photo Comparison

Locations	Earliest Photo Date	Average Channel Width (ft)	Recent Photo Date	Average Channel Width (ft)	Average Width Change (ft)	Width Change (%)
Above Denver Water Diversions – Control Segments						
FR5 Fraser River above Denver Water's Diversion (South Segment)	1985	20	2009	16	-4	-18%
FR6 Jim Creek above Denver Water's Diversion	1985	14	2009	15	1	5%
FR4 Ranch Creek above Denver Water's Diversion (East Segment)	1962	11	2009	10	0	-3%
Areas below Denver Water Diversions						
CR1 Colorado River above Parshall	1962	72	2009	82	10	13%
CR2 Colorado River at Kemp-Breeze State Wildlife Area	1983	108	2009	112	4	4%
FR1 Fraser River above Winter Park gage (North Segment)	1962	17	2009	21	4	26%
FR1 Fraser River above Winter Park gage (South Segment)	1962	16	2009	22	6	39%
FR2 Fraser River Near Tabernash	1962	38	2009	48	10	26%
FR3 St. Louis Creek below West St. Louis Creek	1962	25	2009	32	8	31%
FR4 Ranch Creek below South Fork	1962	17	2009	19	2	11%
FR5 Fraser River below Denver Water's Diversion (North Segment)	1985	14	2009	16	2	15%
FR7 Vasquez Creek below Denver Water's Diversion (North Segment)	1988	21	2009	20	1	2%
WF1 Williams Fork Near Sugarloaf Campground	1983	36	2009	40	4	11%
WF2 Williams Fork below Steelman Creek	1985	31	2009	28	-3	-9%
BR1 Blue River below Confluence with Boulder Creek	1983	89	2009	91	2	2%
Areas with Increased Flows						
FR7 Vasquez Creek above Denver Water's Diversion (South Segment)	1988	19	2009	22	2	12%
NF1 North Fork South Platte River Near Shawnee	1985	57	2009	51	-6	-11%
NF2 North Fork South Platte River Near Pine	1963	49	2009	53	4	8%
SBC1 South Boulder Creek above Gross Reservoir	1985	38	2009	37	-1	-2%
SBC3 South Boulder Creek below Gross Reservoir	1983	47	2009	42	-5	-11%

Note:
The aerial photo interpretation required evaluation of long segments of streams and therefore are not limited nor necessarily consistent with the naming of the Representative sites.

Table 4.6.3-2
Historic Stream Sinuosity Comparison

Locations	Sinuosity	Sinuosity (2009)	Change in Sinuosity	% Change in Sinuosity
Above Denver Water Diversions – Control Segments				
FR5 Fraser River above Denver Water's Diversion (South Segment)	1.23	1.28	0.05	4%
FR6 Jim Creek above Denver Water's Diversion	1.13	1.15	0.02	1%
FR4 Ranch Creek above Denver Water's Diversion (East Segment)	1.20	1.23	0.03	3%
Areas below Denver Water Diversions				
CR1 Colorado River above Parshall	1.13	1.12	0.00	0%
CR2 Colorado River at Kemp-Breeze State Wildlife Area	1.50	1.50	0.00	0%
FR1 Fraser River above Winter Park Gage (North Segment)	1.19	1.18	-0.01	-1%
FR1 Fraser River above Winter Park Gage (South Segment)	1.17	1.17	-0.01	0%
FR2 Fraser River Near Tabernash	1.37	1.34	-0.03	-2%
FR3 St. Louis Creek below West St. Louis Creek	1.23	1.24	0.01	1%
FR4 Ranch Creek below South Fork	1.31	1.27	-0.04	-3%
FR5 Fraser River below Denver Water's Diversion (North Segment)	1.23	1.28	0.05	4%
FR7 Vasquez Creek below Denver Water's Diversion (North Segment)	1.67	1.68	0.01	1%
WF1 Williams Fork Near Sugarloaf Campground	1.41	1.41	0.01	0%
WF2 Williams Fork below Steelman Creek	1.17	1.16	-0.01	-1%
BR1 Blue River below confluence with Boulder Creek	1.12	1.12	0.00	0%
Areas with Increased Flows				
FR7 Vasquez Creek above Denver Water's Diversion (South Segment)	1.28	1.22	-0.06	-5%
NF1 North Fork South Platte River Near Shawnee	1.13	1.14	0.01	1%
NF2 North Fork South Platte River Near Pine	1.30	1.30	0.00	0%
SBC1 South Boulder Creek above Gross Reservoir	1.06	1.07	0.01	0%
SBC3 South Boulder Creek below Gross Reservoir	1.34	1.37	0.03	2%

Note:
The aerial photo interpretation required evaluation of long segments of streams and therefore are not limited nor necessarily consistent with the naming of the Representative sites.

At control segments above Denver Water's diversions, increases in sinuosity were recorded at all three sites, however the calculated increases ranged from only 1 percent (%) to 4%. Average increases at these three sites were calculated to be less than 3%. Sinuosity changes at the 12 stream segments below Denver Water's diversions included four sites with calculated decreases in sinuosity (between 1% and 3%), five segments with no apparent changes and three sites with slight increases (between 1% and 4%). On average these 12 segments were found to have a decrease of less than 0.1%. Sinuosity changes at the five sites with increased flows included one site with a calculated sinuosity reduction (5%), two sites with no change and two sites with a calculated increase in sinuosity ranging from 1% to 2%. On average the five sites with increased flows were calculated to have an average change in sinuosity of -0.4%.

Changes in sinuosity are believed to be within the accuracy of measurement techniques. No trends showing differences in stream sinuosity were identified.

At control segments above Denver Water's diversions, an apparent increase in stream width was calculated at one site while decreases were calculated at two of the sites. On average these three stream segments were found to decrease in width by an average of 5%. Calculated channel width changes at the 12 stream segments below Denver Water's diversions included 11 sites with calculated decreases in width (between 2% and 39%) and one segment with a calculated width increase (9%). On average the calculated channel width was found to increase by 16% at the 11 sites showing increase. Including all 12 segments, the calculated average channel width increase was found to be 14%. Channel width changes at the five sites with increased flows included three sites with a width reduction ranging from 2% to 11% and two sites with calculated channel width increases ranging from 8% to 12%. On average, the five sites with increased flows were calculated to have an average change in width of 1%.

Changes in channel widths appear to show different trends for segments below diversion structures than for the control segments above diversions and areas where flows have increased. Data suggest that channel widening has occurred below diversions while other areas are showing little change to slight narrowing. Signs of channel widening below diversions were generally not noted in field observations and are contrary to the concept of vegetative encroachment that is suspected at some locations (see Section 3.3). System-wide channel widening below diversions is also contrary to data presented on Stream Cross Sections and Gage Analysis presented below. Overall, it is believed that resolution of imaging, natural changes in vegetation and measurement techniques used to evaluate channel widths as part of the evaluation of aerial photos may have introduced error to the analysis and as a result, trends suggested by this analysis are unclear.

Historic Ground Photos

Limited historic ground photos were available from the 1930s when Denver Water originally constructed the Moffat system. Denver Water also took additional photos from similar locations in 1989-1990. As part of the EIS analysis areas identified in these historic photos were revisited in 2010 and photographed for comparison.

Photo locations are identified on the maps of the various river basins in Figures H-16.1 through H-16.6 in Appendix H-16. Historic photo locations included a site on the Fraser River above the West Portal, a site on the Fraser River below the West Portal, a site on Vasquez Creek near the West Portal, a site on St. Louis Creek, and a site on Ranch Creek near Tabernash (see Appendix H-18).

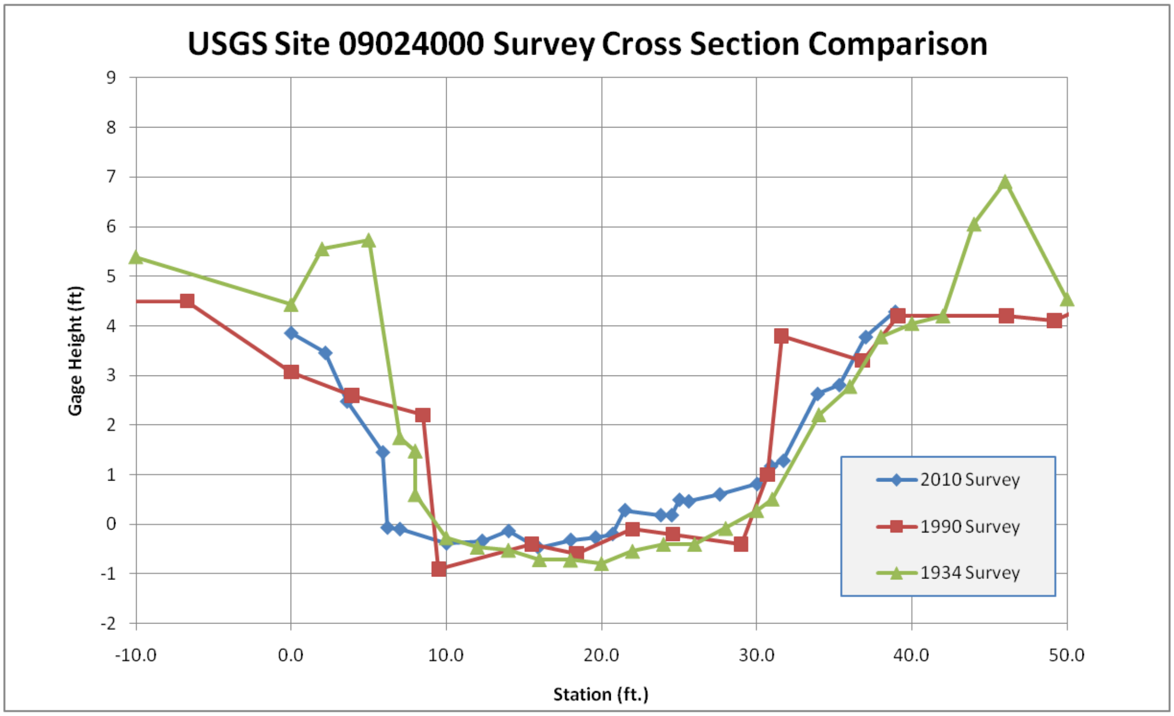
Review of the various photos did not provide insight into past changes in channel morphology that were deemed useful when looking for potential trends.

Channel Cross Sections

Data from the original cross section survey of the USGS stream gage upstream of the Idlewild Campground near Winter Park (USGS 09024000) was obtained from Denver Water's archives including the original survey completed in 1934 and a subsequent survey from 1990. The cross section was resurveyed in 2010 to assess whether any trends in channel movement could be detected that would indicate channel responses to past diversions.

Original benchmarks installed with the gage were identified in the field and used as the basis for the survey. All survey elevations were then related to these benchmarks and recorded in terms of station gage height. A comparison of the 1934, 1990, and 2010 cross section surveys is provided as Figure 4.6.3-1.

Figure 4.6.3-1
Historic Cross Section Comparison – Fraser River Near Winter Park



In order to compare the surveys, the total cross sectional areas available to flow at different gage heights were determined (see Table 4.6.3-3). It should be noted that surveys completed in 1934 and 2010 included more individual data points than the survey in 1990. Accuracies of the initial and 2010 surveys are therefore likely somewhat better than the accuracy of the 1990 survey.

Table 4.6.3-3
Historic Cross Section Comparison – Fraser River Near Winter Park

Gage Height (ft)	Flow Area in 1934 (ft^2)	Flow Area in 1990 (ft^2)	% Change in Area Since 1934	Flow Area in 2010 (ft^2)	% Change in Area Since 1934	% Change in Area Since 1990
0.0	9	8	-11%	4	-56%	-50%
0.5	20	18	-10%	13	-35%	-28%
1.0	32	29	-9%	24	-25%	-17%
1.5	43	41	-5%	37	-14%	-10%
2.0	57	52	-9%	50	-12%	-4%
2.5	70	63	-10%	65	-7%	+3%
3.0	85	78	-8%	81	-5%	+4%
3.5	100	94	-6%	98	-2%	+4%
4.0	116	114	-2%	116	0%	+2%

The following observations can be made from the data:

- Flow area has decreased from 1934 to 1990 to 2010 at lower gage heights
- Levees appear to have been constructed as part of the initial gage installation; these levees have since eroded (see Figure 4.6.3-1)
- A thalweg (i.e., the deepest part of a channel) appears to have developed with low flows concentrated near the left bank
- Sediment deposition appears to be occurring near the right bank
- Slight widening of the channel may be occurring near the left bank
- Not all trends were observed consistently from 1934 to 1990 and then from 1990 to 2010 indicating some natural variability in channel shape
- Flow areas at the approximate bankfull elevation of 4 feet have remained relatively stable from 1934 to 1990 to 2010.

The analysis of the cross section on the Fraser River indicates that minor variation in the channel has occurred over the past 76 years. Overall data suggests that a minor amount of aggradation has occurred at the base of the channel with the volume of aggraded material being offset by slight erosion of one channel bank. The total flow area at bankfull flow has not changed and no significant changes in the stream morphology were detected as the minor changes are believed to be within the range of natural variability.

Gage Analysis

An analysis of historic stream flow gages was completed to aid in the assessment of channel morphology. This assessment was conducted to supplement conclusions drawn from direct observation, provide quantifiable data showing past trends of possible channel aggradation or degradation and as a way to check sediment transport model results. The gage analysis focused on sites within the Fraser and Colorado river basins with long periods of record.

The USGS takes measurements at its gage stations allowing it to correlate stream flow with water level. The relationship between these two variables produces the gage rating data. Irregularities and/or changes in the stream bed, hydraulic control features and physical stream flow measurements taken by the USGS lead to variability in the relationship between stream flow and water level. As conditions require, the USGS may change a stream gage's rating to more accurately reflect Current Conditions.

Changes in USGS rating curves can therefore be used as a tool to assess changes in the streambed and overall conveyance of the channel which indirectly provide information on possible sediment accumulation or degradation. Rating curves that show a continued trend where the gage height associated with a given flow increase over time may be a sign of channel aggradation. In such a case it is possible that sediment is depositing in the channel thereby requiring a greater flow depth to pass the same flow. Rating curves that show a continued trend where the gage height for a given flow decreases over time may be a sign of channel degradation. Gages that do not change may indicate stream segments that are neither aggrading nor degrading.

Long-term gaging data from seven stations in the Project area were used as part of the EIS analysis. These stations were selected based on their location in the Fraser and Colorado river basins and the availability of long-term gaging records. Gage locations are shown in the basin maps provided in Figures H-16.1 to H-16.3 in Appendix H-16. All gaging station data used in this analysis was provided by the USGS. Station identification and locations are provided in Table 4.6.3-4.

Table 4.6.3-4
USGS Stream Gage Locations

Station Description	Station ID	Latitude	Longitude
Fraser River above Winter Park, Colorado	09022000	39° 50' 45"	105° 45' 05"
Fraser River at Winter Park, Colorado	09024000	39° 54' 00"	105° 46' 34"
St. Louis Creek Near Fraser, Colorado	09026500	39° 54' 36"	105° 52' 40"
Ranch Creek Near Fraser, Colorado	09032000	39° 57' 00"	105° 45' 54"
Williams Fork below Steelman Creek, Colorado	09035500	39° 46' 44"	105° 55' 40"
Colorado River at Hot Sulphur Springs, Colorado	09034500	40° 05' 00"	106° 05' 15"
Colorado River near Kremmling, Colorado	09058000	40° 02' 12"	106° 26' 22"

Each of the seven gaging stations was evaluated at a low, median, and high flow point. Low values represent flows that are exceeded 90% of the time, median flows are exceeded 50% of the time, and high flows are exceeded 10% of the time. Specific flows were determined using USGS Water Data Reports for 2010 (USGS 2011). Exact flows used for the assessment were modified where required to ensure that a maximum number of values per rating table were available with values rounded. Flow values used for the assessment are provided in Table 4.6.3-5.

Table 4.6.3-5
Flow Rates for Stream Gage Assessment

Station Description	10% Exceed (cfs)	Selected Value (cfs)	50% Exceed (cfs)	Selected Value (cfs)	90% Exceed (cfs)	Selected Value (cfs)
Fraser River above Winter Park	41	40	4.8	5	2	2
Fraser River at Winter Park	54	50	8.7	8	4.2	4
St. Louis Creek Near Fraser	58	50	10	8	4.8	5
Ranch Creek Near Fraser	29	30	4	10	1.8	3
Williams Fork below Steelman Creek	65	65	3.4	4	0.65	1
Colorado River at Hot Sulphur Springs	517	500	100	100	63	60
Colorado River Near Kremmling	1,790	1,800	749	700	406	400

Utilizing the historic rating tables, a gage height was determined for each identified flow. A straight line equation was applied between gage height data to approximate a corresponding gage height. Gage height values corresponding to the given low, median, and high flows were then plotted as a function of time to define any potential changes in stream conditions. Gage station annual reports, also provided by the USGS, were evaluated to determine any anomalous factors that would result in changes in rating tables. Changes in gaging stations are generally described below. Graphs showing the chronological relationship between gage height and flows are given in Figures H-19.1 to H-19.8 in Appendix H-19. Observed results from the various gages are discussed below.

It should be noted that conclusions below related to long-term degradation or aggradation trends are influenced by the specific beginning and end year selected. Wherever possible the analysis utilized the first and last data points available to assess long-term trends. Conclusions below are based on the longest reliable period of record; different conclusions could be reached depending on the start and end date evaluated.

Fraser River above Winter Park

This gaging station is located approximately one mile upstream from Denver Water’s diversion and in close proximity to U.S. Highway (US) 40. Rating tables at this gage indicate a decrease in gage height versus flow for the low, median and high flow rate over the available period of record of 1968-2010 (see Figure H-19.1 in Appendix H-19). Based on the average of the three flow rates, there is an apparent decrease in the channel bed of approximately 0.13 feet (1.58 inches) over this 42 year period with a similar trend observed at the low, median, and high flow level. Trends appear to be generally consistent over the period of record. A decrease in gage height indicates possible degradation or a removal of streambed material at the control structure although the magnitude of the decrease is believed to be insignificant (0.038 inch per year).

Fraser River at Winter Park

This gaging station is located downstream of Denver Water’s diversion, downstream of the Winter Park Ski Resort and upstream of downtown Winter Park. Rating tables at this gage indicate three distinct periods: 1948-1968, 1968-1969, and 1969-2010. Gage heights generally decreased from 1948-1968, showed a distinct increase from 1968-1969 and showed some variability from 1969-2010, with no significant net change over this most recent time interval. Data for this site, including the full 1948-2010 period and a blow up of the 1969-2010 period are presented on Figures H-19.2 and H-19.3 in Appendix H-19.

From 1968 to 1969 there is a significant adjustment in rating tables. USGS field reports noted an intentional adjustment to the control structure to cause the rating table adjustment. From the field notes, the instream grade control structure was build up on August 15, 1968, causing the observed change in gage rating. This indicates that the change in rating observed from 1968-1969 was caused by human activities and is not attributable to bed aggradation. When comparing results, the shift from 1968 to 1969 was therefore dropped from the EIS analysis. An additional adjustment in the rating data was noted by the USGS for higher flows from 1998-2009. The gage height corresponding to the higher flows during this period is approximately 0.2 feet higher than it is in 1997 and 2010. The USGS indicated in its annual reports that higher flows over the period in question were generated using rating Table 17.0. In 2010 the USGS indicated that results for higher flows developed by this table were believed to be inaccurate and switches to a new rating table (Table 18.0) to correct this concern. For this reading rating information at higher flows from 1998-2009 are questionable and were not used in the EIS evaluation.

From 1948-1968 there was an apparent decrease in the channel bed of 0.28 feet (3.36 inches) based on the average rating change for the three flow rates.

From 1969 to 2010 gage heights show a slight increase at low flows, no change at median flows and a slight decrease at high flows after an anomaly between 1998 and 2009 is dismissed. Adjusting for this anomaly by excluding any bed change over the period in question there was an apparent decrease in the channel bed of approximately 0.12 feet (1.44 inches) from 1969-2010. After factoring out the adjustments made from 1968-1969, there was an apparent decrease in the channel bed of approximately 0.29 feet (3.5 inches) from 1948-2010 based on the average rating change from the three flow rates. A decrease in gage height indicates possible degradation or a removal of streambed material at the control structure although the magnitude of the decrease is believed to be insignificant (0.057 inch per year).

St. Louis Creek Near Fraser

This gaging station is located approximately four miles downstream of Denver Water's diversion structure. Rating tables at this gage indicate a slight increase in gage height versus flow for the low, median and high flow rate over the historical period of 1934-2008 (see Figure H-19.4 in Appendix H-19). A distinct increase of approximately 0.1-0.2 feet occurred in 2009. According to the USGS field report, this increase is believed to have been caused by some large boulders in the control area. This event is considered an anomaly and not indicative of an actual change to the stream bed elevation. For this reason the data points from 2009 and 2010 were not used in our analysis. Excluding these two years and using the average of the three flow rates, there is an apparent increase in the channel bed of approximately 0.07 feet (0.82 inch) over the 74 year period. An increase in gage height indicates possible aggradation although the magnitude of the increase is believed to be insignificant (0.011 inch per year).

Ranch Creek Near Fraser

This gaging station is located approximately two miles downstream of Denver Water's diversion structure. Rating tables at this gage indicate three periods with differing trends, 1934-1962, 1962-1973, and 1973-1995. Gage heights varied from 1934-1962 but showed little net change over this period, showed a significant increase from 1962-1973 and showed trends of stable to slightly increasing heights from 1973-1995 (see Figure H-19.5 in Appendix H-19).

From 1934-1962 there was an apparent decrease in the channel bed of 0.003 feet (0.036 inch or 0.001 inch per year) based on the average of the three flow rates. From 1962 to 1973 there was a significant adjustment in the rating tables. Over this time, the average apparent increase in the channel bed taken as the average from low, median, and high flows was approximately 0.08 feet (0.96 inch). No specific notations were provided in USGS field reports explaining this increase. From 1973 to 1995 gage ratings were initially constant and then started to show a slight increase with increases in 1988 and 1991. There was an apparent increase in the channel bed of approximately 0.05 feet (0.6 inch) from 1973-1995. An increase in gage height indicates possible aggradation although the magnitude of the increase is believed to be insignificant (0.027 inch per year). No explanation for the largest increase from 1962-1973 is known.

William Fork below Steelman Creek

This gaging station is located approximately two miles downstream of Denver Water's diversion structure. Rating tables at this gage indicate slight variation at times but overall little to no net change in gage height versus flow for the low, median, and high flow rate over the historical period of 1965-2010 was identified (see Figure H-19.7 in Appendix H-19). Based on the average of the three flow rates, there was an apparent decrease in the channel bed of approximately 0.01 feet over this 45-year period with no discernable trends over the time noted. Little to no change suggests minimal aggradation or degradation of the streambed at this location.

Colorado River at Hot Sulphur Springs

This gaging station is located near the Town of Hot Sulphur Springs well downstream of all of Denver Water's diversions. Rating tables at this gage indicate an increase in gage height versus flow for the low, median and high flow rate over the historical period of 1935-1994 (see Figure H-19.6 in Appendix H-19). Based on the average of the three flow rates, there was an apparent increase in the channel bed of approximately 0.25 feet (3 inches) over this 59 year period. The rate of the channel bed increase has been relatively constant over the period of record. USGS field notes for 1970 indicate fill occurred at the gage control structure that contributed to these increases. In addition, the USGS suggests that the larger increases occurring at higher flows were related to vegetation and brush growth although the apparent rate of increase was generally consistent at low, median, and high flow levels and vegetation was unlikely to have impacted the rating table at low and median flows. An increase in gage height indicates possible aggradation although the magnitude of the increase is believed to be insignificant (0.051 inch per year).

Colorado River Near Kremmling

This gaging station is located near the Town of Kremmling, approximately three miles downstream from the confluence with the Blue River and well downstream of all of Denver Water's diversions. Rating tables at this gage indicate an increase in gage height versus flow for the low, median and high flow rate over the historical period of 1961-2010 (see Figure H-19.8 in Appendix H-19). Based on the average of the three flow rates, there was an apparent increase in the channel bed of approximately 0.8 feet (9.6 inches) over this 49 year period. An increase in gage height indicates possible aggradation at a net rate of 0.20 inches per year. The rate of the channel bed increase has been relatively constant at low, median and high flows through 2005 although the opposite trend of an apparent bed decrease is observed from 2005-2010.

A summary of the average annual change in bed elevations derived based on gaging data is presented in Table 4.6.3-6 below. These values include readings that were believed to be accurate and exclude the specific anomalies previously described.

Table 4.6.3-6
Calculated Changes in Gage Height

Station Description	Low Flow (in./yr)	Median Flow (in./yr)	High Flow (in./yr)	Average (in./yr)	Cumulative Total			
					Low Flow (in.)	Median Flow (in.)	High Flow (in.)	Average (in.)
Fraser River above Winter Park	-0.036	-0.037	-0.040	-0.038	-1.50	-1.56	-1.68	-1.58
Fraser River at Winter Park	-0.045	-0.049	-0.076	-0.057	-2.82	-3.06	-4.74	-3.54
St. Louis Creek Near Fraser	0.002	0.011	0.019	0.011	0.12	0.86	1.48	0.82
Ranch Creek Near Fraser	0.077	0.061	0.061	0.066	4.68	3.72	3.72	4.04
Williams Fork below Steelman Creek	-0.005	0.005	0.007	0.002	-0.24	0.24	0.30	0.10
Colorado River at Hot Sulphur Springs	0.040	0.061	0.053	0.051	2.34	3.60	3.12	3.02
Colorado River near Kremmling	0.247	0.220	0.120	0.196	12.12	10.80	5.88	9.60

Data suggests that apparent changes in the bed elevations over the period where stream gage data are available are generally minor. Of the seven stations, average changes at six of the stations were less than ±0.07 inch per year (0.0055 feet per year). These changes are considered to be insignificant and within the natural variability expected in the system. The greatest apparent change in the bed elevation was observed from the rating data for the Colorado River near Kremmling site where average annual changes were more than 3 times greater than at any other station. The gage analysis indicates that the bed at this location may be aggrading at a long-term average annual rate of 0.2 inch per year. Changes are most pronounced after approximately 1986, however data indicates a slight lowering of the channel bed from 2005-2010.

Diversions and flow depletions have increased over time. If past diversions led to sediment deposition then overall channel aggradation trends of bed increases would likely have been observed, with greater changes in more recent years when diversions were the highest. The absence of these trends suggests that systematic sediment deposition has not occurred to this point in time in the Project area.

4.6.3.2 Review of Previous Studies

Previous studies relating to channel morphology were reviewed as part of the EIS. Specific attention was paid to studies conducted within the Project area and those related to impacts of diversions on downstream channel systems. A brief summary of some of the more relevant studies is provided below. Summaries generally include how and where the study was conducted, its results as they relate to the issue of channel morphology for the Moffat Project and how study results were used for this analysis.

Ryan 1997

Ryan evaluated channel response to historic diversions to determine whether differences in channel form can be detected in subalpine step-pool, plan bed, or pool riffle channel resulting from past flow diversions. Research was completed on nine headwater streams in Colorado with six portions of stream segments in the Project area including the Fraser River, Vasquez Creek, St. Louis Creek, East St. Louis Creek, West St. Louis Creek, and the Williams Fork River. Ryan's study focused on measuring channel width at locations impacted and unimpacted by stream diversions to quantify differences at locations above and below diversions. It was her hypothesis that channels would be narrower below diversions as a result of infilling and vegetative encroachment.

Results of the study indicated that channel narrowing did occur downstream of diversions, but observable changes were limited to locations where the stream below the diversion was unconstrained and wide. Observed changes were generally limited to the widest pool-riffle sections with cobble bars. Areas of width reduction were observed to be reaches that were already unstable. No measurable differences were found in constrained streams. Ryan suggested that the absence of widespread channel response was likely attributed to periodic higher flood flows such as 5- and 10-year recurrence which act to rejuvenate the channels.

This study provides insight as to anticipated responses to flow changes resulting from the Moffat Project. Based on research by Ryan, it is expected that additional deposition may be expected in wider areas that are currently depositional areas. Changes in channel width are not predicted in streams with higher gradients, confined sections and areas where channel width is typical. These areas are predicted to remain largely unimpacted in terms of channel morphology assuming that higher magnitude; lower frequency flood events are not significantly altered.

Based on Ryan's conclusions, an analysis of the magnitude and frequency of the 5- and 10-year flows was conducted. Results from each Project alternative were compared with Current Conditions (2006) to assess changes to these large, infrequent events that were believed to be responsible for maintaining channel morphology throughout a majority of the downstream stream systems.

Baker et al. 2010

Baker evaluated channel response to historic diversions to determine if fine sediment deposition and habitat changes occurred in downstream stream segments. Research was completed in 13 study sites in Colorado and Wyoming and included sites on the Bobtail Creek, Ranch Creek, Steelman Creek, and St. Louis Creek which are within the Moffat Project area. Baker's study focused on comparing sediment composition and habitat types above and below diversions with the hypothesis that stream reaches below diversions contained more fine material and different habitat types. Analysis included stream measurements at one or two points in time and did not include an assessment of diversion records or historic operations.

Results of the study indicated that stream reaches downstream of diversions generally had increased fine sediment and more pool habitat than reaches upstream of diversions. Increases in fine sediment were limited to stream segments with slopes less than 3%. Hydraulic properties of flow velocity, shear stress, and stream power were found to be lower downstream than upstream of diversions. The amount of slow water habitat was found to increase with the percent of diversion.

Measurements from the four streams in the Moffat study area did not always follow the general observed trends. The observed percentage of pool habitat increased below the diversion at Bobtail Creek and Steelman Creek, decreased below the diversion at Ranch Creek, and remained nearly unchanged from above to below the diversion for the two readings on St. Louis Creek. The volumetric percent fines measured in fast water and as measured by pebble counts increased from upstream of the diversions to downstream of the diversion in four of the five measurements in the Moffat Project area. The volumetric percent fine measured in slow water and the aerial percent fines measured in fast water, however, decreased from upstream to downstream of the diversions in three of the five measurements while the aerial percent fines increased in three of the five readings.

Results suggest that the amount of fine sediment and slow water habitat will tend to be higher downstream of a diversion. Findings suggest that the amount of slow water habitat may increase as the percent of flow diverted increases, but changes to fine sediment were not found to be related to the percentage of natural flow diverted. For the proposed Moffat Project, these findings suggest that more slow water habitat will be available in areas where diversions are increased, but the percentage of fine sediment is not anticipated to change with increased diversions as this parameter was not found to be correlated with percent of flow diverted. As the study indicates, limitations result from the fact that this study considered only single points in time and it may not be appropriate to extrapolate from the results of this study.

Albano 2006

The Albano paper is a master's thesis on the impacts of flow diversions to the structural and functional response to macroinvertebrate communities to different magnitude flow reductions. Sample sites included 14 stream diversions measured either during the summer and/or fall of 2005. Site locations include all of the sites utilized for the Baker et al. study (Baker et al. 2010) and include the four locations within the Moffat Project area. Macroinvertebrate and fine sediment were collected at each sample location and related to the portion of flow change resulting from the diversion.

Study results found that the taxonomic and functional composition of macroinvertebrate communities was impacted when >90% of flows were diverted. At these diversion levels the number of some rheophilic taxa decreased while the number of burrowing types of taxa increased. Increases in pool habitat below diversions were coupled with increases in macroinvertebrate densities, richness, and diversity. Steeper gradient streams were more sensitive to flow diversions and exhibited the largest changes. Fine sediment deposition was not found to have a significant impact on macroinvertebrate community metrics and it was concluded that deposition likely did not negatively affect communities.

Wetted channel bed area and average flow depth and velocity were found to decrease below diversions while the proportion of slow water habitat increased. Wetted bed area, average velocity and the proportion of slow habitat were found to be proportional to flow diversions with changes in velocity observed when diversions exceeded 50% and slow habitat increased with diversions greater than 70%. Decreases in depth were not found to correspond to diversion magnitude. Minimal changes in proportion of fine sediment, as measured by area and mass, were observed at the sample sites.

This research suggests that flow diversions contemplated for the Moffat Project may alter downstream channel characteristics. Increases in slow water habitat may occur where flow diversions exceed 70% and flow velocities are likely to decrease when diversions exceed 50%. Based on this research, changes in the proportion of fine sediment above and below diversions is not expected to change.

Bohn and King 2000

Bohn and King evaluated the effects of small, low-head seasonal water diversions on downstream channels. Their research was conducted in small snowmelt driven forest streams in the Snake River Basin in Idaho, Oregon, and Wyoming. The study specifically evaluated whether diversions changed flow conveyance, substrate sediment size distribution or streamside vegetation downstream from a diversion. A majority of the streams studied had a small portion of the flow diverted all or parts of the year, typically with no impoundments.

Results of the study indicate that stream flow conveyance below diversions were less than conveyance above diversions. Changes in conveyance were thought to be greater in streams with higher flows. Changes in conveyance were not correlated to stream gradient and the study did not indicate whether conveyance loss was related to the portion of flow diverted. No statistical difference was noted in the substrate particle sizes and channel roughness above and below diversions. This indicates that fine sediment was not observed to be increasing below the diversions. Sediment transported in the flows upstream of diversions was found to be greater than that transported downstream of the diversion, however it is likely that some of the bedload is carried in the diverted water, limiting downstream loads.

Findings suggest that channels downstream of diversions in the Moffat system are susceptible to reduced conveyance, which indicate that encroachment may occur. Possibility of encroachment is greatest in larger streams, however results did not indicate encroachment was related to the percentage of water diverted. Based on these results, changes in sediment sizes, including the amount of fines are not expected downstream of diversions. Decreases in sediment transport observed in the study are not believed to be relevant to the Moffat Project as the study did not evaluate transport in diverted water.

Wong and Parker 2005

Wong and Parker reevaluated the dataset and sediment transport equation derived for the original 1948 Meyer-Peter and Müller (MPM) equation. Their study indicated that an unnecessary correction factor was applied in the derivation of the 1948 equation. Using the revised MPM equation the new estimates of bedload transport rates are approximately half of the values obtained with the original MPM equation.

This research is relevant to the Moffat Project since analysis in the Draft EIS utilized the original MPM equation for sediment transport calculations. The MPM equation was still utilized in the evaluation of sediment transport, however modeling presented in the Final EIS used the modified version of the equation.

Schmidt and Potyondy 2004

Schmidt and Potyondy evaluated flow necessary to maintain the physical characteristics of the stream channel for unimpaired flow and sediment transport. The analysis focused on snowmelt dominated coarse-grained gravel bed streams in the Rocky Mountains. The paper considered the flows necessary to transport finer sediment and coarser material. The analysis focused on bedload and used only bedload transport for the analysis. While suspended sediment usually constitutes a majority of the total sediment load, they noted that it was not relevant for evaluation of channel morphology of gravel-bed rivers.

Fine sediment load is often supply limited and comprises a large portion of the annual bedload. In gravel-bed rivers, coarse material is typically only mobilized during higher flows. Fine sediment consisting of fine gravels and smaller material are typically moved as part of Phase 1 sediment transport. Movement of larger materials is termed Phase 2 transport. The onset of Phase 2 transport is important to channel maintenance as it begins the mobilization of channel bed material. Due to the supply limited nature of gravel bed streams, flows in a narrow range above the flow required to initiate Phase 2 transport can move nearly all of the bedload sediment without compromising channel maintenance. Retaining flows adequate to achieve and exceed Phase 2 transport provide the minimum flows required to achieve channel maintenance objectives.

The concept of Phase 2 sediment transport was utilized as part of the analysis of anticipated impacts resulting from the proposed Moffat Project. Retaining flows necessary for Phase 2 transport is important for maintaining channel morphology. The flow required for the onset of Phase 2 sediment transport was calculated for each of the Representative sites. Changes in the frequency at which Phase 2 transport occurs were evaluated to quantify impacts of proposed diversions with Current Conditions (2006) to assess potential impacts.

The EIS analysis also focused on bedload sediment and dismisses suspended sediment. While suspended load typically comprises a majority of the total sediment load, it is not important in terms of channel morphology and therefore was not included in calculations of transport capacity.

Ryan et al. 2002

Ryan et al. evaluated the relationship between bedload and discharge to determine a breakpoint between Phase 1 and Phase 2 sediment transport. The study was based on research completed at the Fraser Experimental Forest near Fraser, Colorado. Sampled streams included six segments on St. Louis Creek and single segments on East St. Louis Creek and Fool Creek, all of which are located within the Moffat Project area.

The study identified the approximately D_{16} sized material taken from the gradation at the surface as an important grain size for sediment transport. Capture of the D_{16} sized particle of the surface layer, which is roughly equivalent to the D_{50} of the subsurface grain size distribution, typically indicated the onset of Phase 2 transport. The onset of Phase 2 transport was related to the 1.5 year discharge event. For the sites evaluated, Phase 2 transport was observed to start when flows ranged from 57% to 95% of the 1.5 year flood. The median value of Phase 2 transport was found to be approximately 80% of the 1.5 year event.

This research was used to define flows required for Phase 2 transport at the various Representative sites. Based on Ryan's research, the onset of Phase 2 transport was defined by the flow necessary to mobilize the D_{16} sized material at each site. All flows equal to or greater than that flow were assumed to cause Phase 2 transport. The frequency and recurrence interval of Phase 2 transport events were defined for the Project alternatives and compared with Current Conditions (2006) to assess Project impacts on channel morphology as well as cumulative impacts from other RFFAs.

Draft Grand County Stream Management Plan Phase 2 (2008) and Phase 3 (2010)

A Stream Management Plan was prepared for stream systems in Grand County. As it relates to channel morphology, the draft Phase 2 and Phase 3 reports present recommendations for flushing flows at 19 sites, evaluate the stability of riffles using a measure of material mobilization and assess channel stability and health.

Recommended flushing flows range from a low of 12 cubic feet per second (cfs) to a high of 2,500 cfs on the various stream segments. It is recommended that flushing flows occur for a duration of 3 days at a frequency of 1 in 2 years during late May to late June. The report summary states that flushing flow recommendations were based on bedload transport modeling aimed to identify a threshold flow at which spawning gravel is mobilized with transport modeling completed utilizing the Parker equation.

Review of information provided in the Grand County Stream Management Plan on transect and bedload threshold plots and tables, however, indicates that the sediment transport modeling performed does not relate back to the recommended flushing flows presented in the management plan. Threshold particle sizes signifying the onset of flushing flows are not identified nor related to the material gradation at the sites. Data presented in tables in the report appendices indicate that recommended flushing flows have shear stress values as low as 0.1 pounds per square foot (psf), which relates to a typical threshold value for very fine to fine gravel (approximately 6 millimeter [mm] particle size) to as high as approximately 1.33 psf, which relates to a typical value for cobble size material (> 64 mm particle size) without rationale for selection. It appears flushing flow recommendations may have been based on the author's judgment independent of consistent technical criteria. Due to the absence of a consistent technical justification for recommended flushing flows presented in the Grand County Stream Management Plan these values were not assumed to be accurate for the EIS. An analysis of the flows required to initiate mobilization of the stream bed (Phase 2 sediment transport) and the recurrence interval and frequency of these flows was therefore used in the EIS.

The stability of riffles on select streams in Grand County was evaluated using the Riffle Stability Index (RSI) method (Kappesser 2002). Results of this study indicated that a large proportion of riffle substrate material had recently been mobilized and little fines were observed in riffles indicating streambeds were generally mobilized in 2008. Dominant large sized particles observed on the bars ranged from a low of 86 mm (small cobble) to 212 (large cobble). In total the dominant large bar particle classified as a small cobble (64 mm-128 mm) at 50% of the sample locations and as large cobble (128 mm-256 mm) in the remaining 50%. Fine sediment was observed in lower gradient areas as it commonly expected. RSI values suggest that flows necessary to mobilize streambeds continue to occur, at least during higher flow years. Caution is recommended for reliance on RSI values for detailed future assessments, however, given that this methodology was developed for streams with slopes between 2% and 4% and only one of the sites in the Grand County Stream Management Plan (Vasquez Creek) fits this criterion.

Data collected as part of the EIS provide insight into channel morphology that was useful as part of the evaluation of channel morphology. At all sites evaluated, the dominant large particles on the bars classified as either a small cobble or a large cobble. As the size of these particles represents the size of bedload that is transported at normal high flows (Kappesser 2002), it was concluded that typical high flows have the energy to transport cobble sized materials in all measured streams. This information indicates that typical high flows exceed the threshold of Phase 2 sediment transport based on the observed particle sizes.

Channel stability was evaluated in the Grand County Stream Management Plan using the Stream Reach Inventory and Channel Stability Evaluation (SRI/CSE) procedure developed by the U.S. Forest Service (USFS). SRI/CSE is intended to provide information on a channel's capacity to adjust and recover from changes in flow and sediment. Thirty-one stream segments were evaluated with no segments categorized as "Excellent," 14 segments categorized as "Good," 17 categorized as "Fair," and no segments categorized as "Poor." Channels in steeper segments were typically found to rank higher than those with lower gradients. The U.S. Environmental Protection Agency (EPA) Rapid Assessment Protocol method was utilized in the Grand County Stream Management Plan to assess habitat characteristics on 31 stream sections. No sections were categorized as "Optimal," 27 sections were categorized as "Suboptimal," 4 segments were categorized as "Marginal," and no segments were categorized as "Poor." Low stream sinuosity was the individual attribute that was most commonly scored low. SRI/CSE and EPA Rapid Assessment results support field observations that past diversions and land practices have generally not resulted in poor conditions.

Barry et al. 2006

This study looked at the performance of commonly used sediment transport equations at predicting bed load transport in mountain gravel rivers in the western United States. The authors also evaluate the ability of different sediment transport equations to predict effective discharge. Sediment measurements from 22 sites throughout Oregon, Wyoming, and Colorado were used as the basis for this study. The equations evaluated for the Barry et al. study (2004) included the MPM (1948), Ackers and White (1973) (as modified by Day [1980]), Bagnold (1980), Parker (1990), and Barry et al. (2004).

Findings of the study were that equations that contain a threshold for transport incorrectly predict zero transport at low flows. The MPM and Bagnold equations typically under predict total transport due to the high number of incorrect zero predictions. They found that predictions of bed load transport made by the MPM and Bagnold equations improve significantly when predicted transport was increased. Results of the study indicate that Ackers and White and Barry equations outperformed the others with the MPM and Bagnold equations outperforming the Parker equation when errors for under predicting transport at low flows were corrected (Barry et al. 2006). The authors also found that all five equations were accurate at predicting the effective discharge and concluded that the choice of transport equations for this purpose was not as critical.

This study is significant to the Moffat Project as the MPM and Parker equation are two equations that have been used to assess sediment transport. Results suggest that values of sediment transport predicted using the MPM equation underestimate actual transport at low flow but that the MPM equation tends to outperform the Parker equation after factoring in low flow zero transport values. Results also indicate that the predicted value of effective discharge is not strongly influenced by the sediment transport equation that is selected.

Bledsoe and Beeby 2012

A report titled “Sedimentation Processes and Effects in the Fraser River and its Tributaries” (Bledsoe and Beeby 2012), was prepared for Trout Unlimited. The study’s intent was to evaluate conditions in the Fraser River and tributaries and assess potential sediment related impacts from the proposed Moffat Project. Bledsoe and Beeby (2012) included reporting on limited field observations, an analysis of stream bed elevation at a single USGS gage on the Fraser River, estimates of change in sediment transport capacity and a flow frequency and duration analysis.

Bledsoe and Beeby’s field reconnaissance lead them to conclude that aggradation is currently occurring in the main stem of the Fraser River. This conclusion was based on qualitative observations of fine sediment stored in bars, other sand deposits and embedded substrate at several locations.

The stream gage analysis presented in the Bledsoe and Beeby report (2012) considered the change in stream stage at a single USGS gage. The Bledsoe and Beeby report considered apparent change in flows at the Winter Park gage, and was limited to data starting in 1984. Conclusions reached in the Bledsoe and Beeby report (2012) suggest a pattern of increased bed stage, which are stated to likely be the result of sand flux through the system. The stream gage analysis completed by Bledsoe and Beeby did not utilize the available gage data prior to 1984 (which would likely have led to a different overall conclusion on long-term trends in the gage elevation) nor considered other regional USGS gages.

Effective discharge is discussed as a main topic in the Bledsoe and Beeby report (2012), however, the report does not define an actual effective discharge nor how it may or may not be impacted by the Moffat Project. Rather, the Bledsoe and Beeby report provides calculations as to the magnitude of change in sediment transport capacity from current flows to the Proposed Action. Base hydrology data used for the Bledsoe and Beeby report (2012) appear to be derived in part from the PACSM results and part independently by Bledsoe and Beeby; therefore, the background hydrologic data used for numeric analysis are different than that in the EIS. Bledsoe and Beeby conclude that flow reductions that result from the Proposed Action would generally decrease sediment transport capacity in the main stem of the Fraser River and tributaries, with individual reductions ranging from 0% to approximately 70% at different locations and for different flow regimes. The Bledsoe and Beeby report (2012) does not evaluate sediment supply nor does it address locations where the streams are sediment supply limited verses transport capacity limited.

The shear stress analysis presented by Bledsoe and Beeby describes the frequency that flows exceed specific dimensionless shear stress values for current flow conditions and for the Proposed Action using hydrology data that was generated by them for the analysis. The duration and frequency that these flows were exceeded given the Proposed Action was found to be reduced when compared to current flows. Flows exceeding the threshold predicted to mobilize the bed armoring were predicted by Bledsoe and Beeby to still occur on average of between 2.6 and 15.9 days per year at six of the seven sites evaluated. At the seventh site, flows required to mobilize bed armoring were predicted to occur once in 45 years given the Proposed Action verses twice in 45 years given Current Conditions. The results of the shear stress analysis lead to the conclusion that the time between flushing events would increase as a result of the Proposed Action.

The Bledsoe and Beeby study (2012) is significant to the Moffat Project as it evaluated many similar channel morphology features and parameters as the EIS, albeit with a more narrow focus in terms of geographic extent and parameters evaluated. Some of the conclusions presented in the Bledsoe and Beeby report match well with the EIS, while in other places, conclusions are contrary. The Bledsoe and Beeby report and the EIS both conclude that sediment transport capacity and the frequency of higher shear stress flows would be reduced in most sections of the Fraser River Basin. The Bledsoe and Beeby report does not evaluate sediment supply nor whether different stream segments are currently sediment supply limited, while the EIS does. The EIS concludes that streams are generally supply limited and therefore the reduction in sediment transport capacity does not equate to long-term channel aggradation. The Bledsoe and Beeby report (2012) concludes that USGS gage data indicates the bed elevation on the Fraser River is rising over the long-term while the EIS concludes that this is not the case. The difference in this conclusion is believed to be attributable to the fact that the EIS considered a longer period of record starting in 1948, and the EIS accounted for uncertainty in high flow readings from 1998-2009 reported by the USGS. When considering the longer record and problems with high flow records, data in the EIS do not indicate a long-term trend of increased channel elevation at this location.

4.6.3.3 Sediment Supply Methodology

Sediment supply data at the Representative sites are based upon data collected for the channel dynamics impact analysis conducted for the Metropolitan Denver Water Supply EIS (Two Forks EIS) (Simons 1986). Detailed field data collection was completed as part of the Two Forks EIS including sampling of suspended and bedload sediment. Detailed sediment sampling was conducted at 17 sites which were selected by the USFS as being representative of the types of streams in the basins. Site selections made by the USFS were based on reconnaissance flights, aerial mapping, and on-the-ground assessments (Simons 1986). Sites selected by the USFS included 8 locations in the South Platte River Basin, 2 in the Blue River Basin, 5 in the Williams Fork River Basin, and 1 in the Fraser River Basin. Relationships between measured stream flow and sediment were derived based on these measurements.

For the sites studied in 1986 that are in close proximity to the Representative sites in the Project area, the U.S. Army Corps of Engineers (Corps) compared Rosgen Level I stream type, land use, and stream channel attributes including bed surface grain size distributions, channel cross sections, and reach slopes in determining the applicability of the 1986 sediment supply data to Current Conditions and use in this study. It was concluded that the Level I stream types and valley characteristics of sites studied in 1986 accurately represent the Representative sites for the Moffat Project. Surface grain size distributions presented in the 1986 report indicate that both median grain sizes and overall size ranges were consistent with data collected and observations made by the Corps. Overall, land use in the affected basins has not changed significantly since 1986, suggesting that current sediment supply is comparable to that measured in 1986.

Total sediment supply (both bedload and suspended load) was related to discharge by fitting a power curve using the least squares method as follows. The sediment supply equation generated from the Two Forks EIS sampling is:

$$\mathbf{Q_s = a*Q^b}$$

Where:

Q_s = total sediment discharge (tons/day)

Q = water discharge (ft^3/s)

a = regression coefficient

b = regression exponent

Site specific sediment supply relationships were developed for the Moffat Project EIS. For Representative sites evaluated for the Moffat Project EIS that are in close proximity to the sediment sampling sites from the Two Forks EIS, the site specific sediment supply equation was applied. For all other Representative sites, the general sediment supply equation developed by Simons and Associates was applied given the consistency in Level I stream type and bed sediment characteristics. Sediment supply equations used in this analysis are given in Table 4.6.3-7.

Table 4.6.3-7
Sediment Supply Equations

Reach Location	Sediment Supply Equation
Fraser River Sites Colorado River Sites South Boulder Creek Sites	$Q_s = 0.0394*Q^{1.12}$
Williams Fork River Site WF1 - Site WF2	$Q_s = 0.00313*Q^{1.5829}$ $Q_s = 0.02015*Q^{0.9407}$
Blue River Site	$Q_s = 0.01386*Q^{0.994}$
North Fork South Platte River Site NF1 - Site NF2	$Q_s = 0.0144*Q^{1.35}$ $Q_s = 0.00003*Q^{2.38}$

The general sediment supply equation was compared to sediment sampling completed by the USFS as part of their work in the St. Louis Creek drainage in Grand County. Sediment data from this area was collected by the USFS between 1992 and 1997 (http://www.fs.fed.us/rm/data_archive/dataaccess/FEF_bedload_transport.shtml).

Data collected by the USFS was plotted and a best fit curve developed. A third order polynomial was fit to the data with the resulting equation of:

$$\mathbf{Q_s = 0.0091*Q - 7x\ 10^{-6}\ *Q^2 + 2x\ 10^{-6}\ *Q^3}$$

Where:

Q_s = total sediment discharge (tons/day)

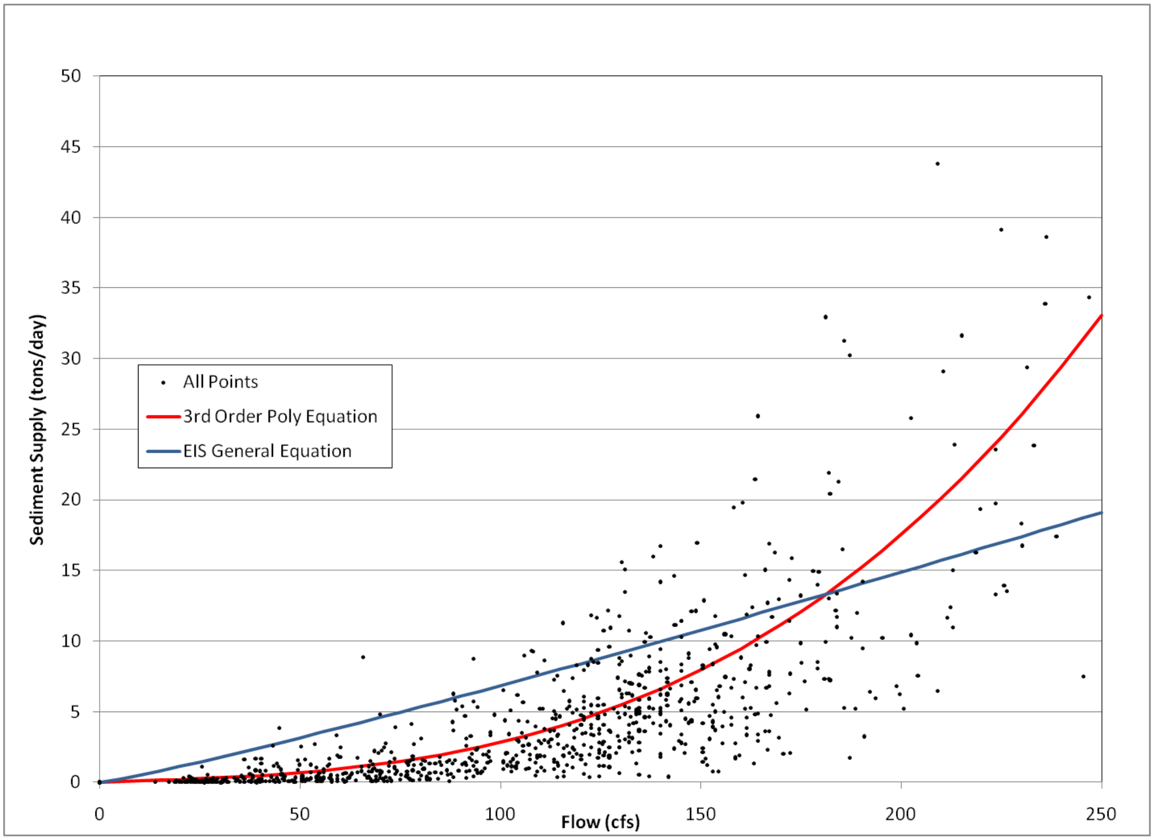
Q = water discharge (ft^3/s)

A comparison of sediment measurements taken by the USFS compiled from the on-line data, the equation developed based on a best fit of the data points and the general equation used for the Moffat Project EIS is provided on Figure 4.6.3-2.

It should be noted that the general equation used in the Moffat Project EIS is an equation for total sediment load, and includes both suspended load and bedload where the St. Louis Creek data is only bedload. This suggests that the sediment load predicted by the general equation would be greater than that predicted by fitting the curve to the data derived from USFS sampling on St. Louis Creek. This is especially true at lower flows due to a majority of sediment transported at lower flows likely being suspended.

Due to the variability in sediment supply measurements and calculations, it was not anticipated that the St. Louis Creek curves would exhibit an exact correlation with the general equation. Overall, the comparison of the general equation with USFS data shows they are similar.

Figure 4.6.3-2
Comparison of Sediment Supply Equations



Variability undoubtedly exists within sediment supply measurements and calculations, but it is believed that the general sediment supply equations developed from extensive field work in 1986 are appropriate surrogates for conducting sediment supply sampling at each Representative site. Comparisons of supply calculations using the general supply equation and the equation derived from USFS data are provided as part of sediment supply calculations below to provide an indication of supply variability introduced by the equation.

Sediment transport having the greatest impact on channel morphology is transport that occurs once the stream channel becomes mobilized. This concept, known as Phase 2 sediment transports, is discussed in detail below.

Traction Sand

Traction sand applied on US 40 in locations adjacent to the Fraser River has the potential to impact sediment supply and transport. A portion of the road sand that is applied is conveyed to the Fraser River despite efforts to control this material and vegetative buffers that exist in most locations between the highway and the river. This input of material increases the fine sediment load in the stream.

A sediment collection facility was recently improved at Denver Water's Fraser River diversion location. This facility captures incoming sediment and provides access for removing sediment from the system. It is intended to help offset sediment loading resulting from traction sand. It is anticipated that this facility will reduce, but not eliminate, traction sand loading into the Fraser River.

These inputs of sediment will have differing impacts on sediment supply and transport. The input of this material is likely to cause areas where localized sediment surpluses exist, particularly immediately following winter when road sanding is prevalent. During higher spring and early summer flow, additional sand supply can increase the transport rate of both sand and gravel sized materials. When sand content increases to the 10% to 30% range, the stream bed transitions from being supported by the gravel framework (framework supported) to being supported by the matrix of sand (matrix supported). The result can lead to large increases in transport rate for both sand and gravel sized particles with increased sand content (Wilcock et al. 2009). It is difficult to model these contrasting increases in both supply and transport capacity as both vary in time and space. While not incorporated quantitatively in the assessment, they are considered when evaluating likely impacts of the Project alternatives and cumulative effects.

Pine Beetle

Areas in Denver Water's supply system have been significantly affected by pine beetle infestation, so the potential for pine beetles and indirect effects of the beetle with respect to potential impacts on sediment supply and transport was evaluated in the EIS. Trees killed by pine beetle could result in decreased sediment supply as dying forests decrease overhead shading resulting in increased groundcover and mid-story vegetation, therefore decreasing erosion potential. Tree mortality from pine beetle could also create increased sediment supply from increased erosion due to a large fire fueled by the dead timber. Since this change in sediment supply could occur with or without the Project with RFFAs, specific impacts to sediment supply were not quantified in the EIS.

In the event of a large-scale fire, sediment supply would likely increase significantly for a finite amount of time. Sediment deposition would be expected to occur in streams during this time from increased erosion potential. As revegetation occurs, sediment supply would decrease. Over time sediment that had been deposited as a result of the fire would begin to be eroded and transported downstream. The river system would continue along this process until it returned to its equilibrium. Given that the Moffat Project with RFFAs would decrease sediment transport capacity in most West Slope rivers within the study area, the time required for the system to return to equilibrium would be greater if an action alternative is implemented. This hypothetical condition was not specifically quantified as part of the analysis.

South Platte River Basin Fires

The Hayman Fire in 2002, followed by flooding and significant erosional events resulted in increased sediment supply from the impacted areas. These increases in sediment supply have created temporary impacts to channel morphology with sediment stored in the channel below impact areas. Based on observations of these areas, flows are continuing to transport this excess sediment downstream. Over time the stream will convey this material through the system bringing the channel morphology back into the conditions that existed prior to the fire. Increases in sediment supply in in the South Platte River were not quantified for the numerical assessment completed on channel morphology as impacts from the fire are temporary.

4.6.3.4 Methods for Quantitative Evaluation of Channel Morphology Analysis

The anticipated effects of the Project alternatives and cumulative effects on channel morphology were evaluated at each of the sixteen Representative sites. The magnitude, frequency and duration of key flow events and sediment transport capacities were quantified and compared to Current Conditions (2006). Key events that were evaluated included the annual sediment transport capacity, onset of Phase 2 sediment transport, the 5- and 10-year flood events and effective discharge. The hydrology dataset used for the different alternatives, different calculation methods and conclusions of cumulative impacts are provided in this section.

Hydrology

Moffat Project alternatives and past actions with RFFAs result in different flow conditions throughout the Project area. Differences in flows have the potential to result in changes in stream morphology. Anticipated flows for each of the Project alternatives with RFFAs were evaluated for the stream morphology assessment. All calculations were based on the daily flow data derived from the 45 years of daily PACSM output. Daily data was then compiled in a variety of manners as required for the specific calculations performed. Different uses of the hydrology data for the channel morphology assessment are described in this section.

Based on PACSM output for the alternatives, hydrologic changes would be similar for certain alternatives. Flow duration curves and flood analyses for each of the alternatives showed little difference between the Proposed Action with RFFAs and Alternative 1c, and between Alternatives 8a, 10a, and 13a. The Proposed Action with RFFAs and Alternative 1c both include 72,000 acre-feet (AF) (77,000 AF with the Environmental Pool for mitigation) of new storage in the Moffat Collection System, with the only difference being the location of new storage on the East Slope (i.e., Gross Reservoir and Leyden Gulch Reservoir). As a result, there is very little difference in hydrologic output between these alternatives. Alternatives 8a, 10a, and 13a have the same or similar quantities of new storage at Gross Reservoir and rely on South Platte River supplies (reusable effluent or transferred agricultural water) to generate 3,000 to 5,000 AF/yr of new firm yield. There is also very little difference in hydrologic output between these alternatives. Therefore, the evaluation of impacts on channel morphology was completed for Current Conditions (2006), Full Use of the Existing System, the Proposed Action with RFFAs, Alternative 8a, and the No Action Alternative.

Daily flow data were used in different ways as part of the channel morphology analysis. Effective discharge calculations require grouping flows into discrete categories or “bins.” For this analysis flow duration curves for each alternative were separated into bins following the USGS flow duration procedure for selecting class intervals. This approach divides the flow data into 35 equal logarithmic class intervals, and is typically applied to rivers having a high incidence of low flows. Both this method and the method of binning flows into equal sized intervals were evaluated. The USGS approach was determined to be appropriate for the EIS rather than utilizing equal sized bins given the number of low and zero flow data points.

Flood frequency analyses were completed to quantify the magnitude of a flood that is expected to occur with different recurrence intervals at each Project alternative at all Representative sites using annual maximum events. Probability plotting and statistical Log-Pearson Type III analyses were conducted to evaluate peak flow frequency. Flood flow rates were determined for the 1.5-, 2-, 5-, 10-, and 50-year events. For most reaches, both methods generated similar flood flows for events that occur more frequently such as the 1.5-, 2-, 5-, and 10-year events. However, differences were often greater for events that occur less frequently, for example the 25- and 50-year events. Differences in flood flows were due in part to the length of the study period (45 years). Longer period of records generally produce more reliable estimates of flood flow rates, particularly for less frequent events. In addition, several of the reaches were located directly below Denver Water's diversions, in which case, natural flow conditions do not exist. Because a Log-Pearson Type III distribution may not be appropriate to fit flow data for reaches located below Denver Water's diversions, results derived from probability plotting was relied on to estimate flood flow rates. Flood frequency curves developed for all alternatives at each of the Representative sites are presented in Figures H-20.1 to H-20.16 in Appendix H-20.

Finally, the channel morphology assessment included an evaluation of the percent of time flows equaled or exceeded a specific flow rate. These frequency calculations were made by directly comparing the flow rate of interest to the full 45-years of daily modeled flow rates and determining the number of days when flows equaled or exceeded the flow rate of interest.

Bedload Assessment

Transport equations used for the analysis consider bedload only. Total sediment transport can be separated into two general classes: bedload and suspended load. Bedload is the portion of grains that are transported along or near the bed of the stream by sliding, rolling or "hopping." Suspended load includes grains that are picked up off the bed and move through the water column. In many streams grains sizes smaller than about ⅛ mm tend to always travel as suspended load and grains coarser than about 8 mm always tend to travel as bedload. Grains between ⅛ mm and 8 mm travel as either bed load or suspended load (Wilcock et al. 2009).

References to sediment transport capacity (a stream's ability to move sediment) in the EIS refer to bedload transport capacity only. While suspended load typically accounts for a majority of total sediment load, bedload is the parameter that is most relevant for the evaluation of channel morphology in gravel bed rivers (Schmidt and Potyondy 2004). As suspended load transport capacity was not calculated, estimates of total sediment transport capacity exclude suspended sediment and therefore understate the actual total sediment load.

Transport Equations

Numeric modeling of sediment transport requires the use of a sediment transport equation. Different sediment transport equations often lead to significantly different numeric results, illustrating the sensitivity to equation selection and uncertainty in numeric model results. Sediment transport in the EIS was therefore calculated using four different transport equations and calculation methods. This approach shows the sensitivity of results to the different equations and allowed for comparison of the various modeled results with field observations. Transport capacity calculations were made using Parker (1990), Wilcock and Crowe (2003), Yang, and the revised Meyer-Peter Müller (MPM) equation. These four transport equations were selected for use in this analysis as they are all derived for the appropriate material size and are equations built into standard transport modeling programs, which allowed transport modeling to be completed with available software.

The use of multiple equations is intended to bound the likely range of actual transport and provide insight into how changes in flow may affect transport without relying too heavily on specific results from a single transport equation that is known to contain uncertainty.

Parker 1990

The Parker equation was developed from transport measurements by Milhous (1973) on Oak Creek, a gravel bed stream in the Coastal Range of Oregon and extrapolation of this dataset. The equation considers transport of multiple grain sizes and is based on the surface gradation of the stream. Sand sized particles are excluded and only larger particles considered. The equation considers a "hiding function." Hiding functions take into account the influence that different particle sizes have on each other.

Wilcock and Crowe 2003

The Wilcock and Crowe equation was derived to consider transport of multiple grain sizes in the sand and gravel range. The Wilcock and Crowe equation is based on the surface gradation of the channel and is similar to the Parker equation; however sand sized particles are included in this equation as the presence of sand increases the mobility of all particle sizes, including gravels (Wilcock et al. 2009). The Wilcock and Crowe equation is based on experimental data.

Yang

The gravel form of the Yang equation was used. The equation assumes that unit stream power is the dominant factor in transport. The Yang equation was based on both laboratory and field data for a wide range of conditions fond in alluvial channels. The Yang equation computes concentrations of bed material discharge in terms of channel velocity and slope.

Meyer-Peter and Müller (MPM)

The Meyer-Peter and Müller (MPM) equation was originally derived in 1948 based on experimental data and has been verified and used extensively in steep gravel, cobble and boulder beds. A reevaluation of the original MPM dataset and subsequent equation was completed by Wong and Parker in 2005. Their evaluation recommended a revision to the original equation that results in calculated bedload transport rates that are approximately half of those determined from the original equation. The modified version of the MPM equation recommended by Wong and Parker was used for this analysis.

Sediment Transport Models

Sediment transport rates used for this analysis include two separate models. Calculations using the Parker and Wilcock and Crowe equations were performed using the BAGS (Bedload Assessment in Gravel-bedded Streams) software developed by the USFS (Wilcock et al. 2009). The BAGS software was developed specifically to compute bedload sediment transport. Flow data, channel geometry data and channel bed gradations are required inputs for the BAGS program. Flow data used for BAGS runs was based on the daily PACSM outputs for each alternative. Minimum and maximum flows were entered into the BAGS program which evaluates flows throughout the defined range based on software generated increments (flow bins). Channel geometry and gradation data used for each Representative site were derived from sediment sampling and site surveys conducted as part of the evaluation of each Representative site. BAGS evaluations were performed for an average cross section for each Representative site.

Sediment transport calculations using the MPM and Yang equation were performed using the Corps' Hydrologic Engineering Centers-River Analysis System (HEC-RAS) computer software. A HEC-RAS model was developed for each Representative site using the channel geometry parameters collected as part of the field assessment. The HEC-RAS hydraulic models were used to generate water surface profiles and other hydraulic and geomorphologic output as a function of discharge for each site. The sediment transport capacity function in HEC-RAS predicts transport capacity for non-cohesive sediment based on hydraulic parameters and known bed sediment properties. Bed sediment properties were determined from surface sediment grain size distributions collected at each site.

4.6.3.5 Methods for Quantitative Impact Analyses

Numerical analyses of sediment transport as it relates to channel morphology were completed at each of the 16 Representative sites. Analyses considered the annual capacity for bed load transport, the flow required to initiate mobilization of the channel bed (Phase 2 transport), the magnitude of peak flood events and the effective discharge for all Project alternatives with RFFAs. In all cases results for the different Project alternatives with RFFAs were compared with Current Conditions (2006) to assess potential impacts to channel morphology.

Annual Sediment Transport Capacity

Calculations were made to determine sediment transport capacity at each of the Representative sites. Transport capacity is the amount of sediment that could be moved, assuming the sediment is available. Results of the different alternatives were compared to Current Conditions (2006) to quantify the cumulative magnitude of transport capacity increase or decrease. Sediment transport capacity was calculated for each of the four transport equations. Given the uncertainty in numeric results from any of the individual transport equations, comparing predicted change derived from the four different equations is intended to provide an indication of the range of transport capacity expected for each Project alternative. For each equation, the predicted sediment transport capacity for a given alternative was completed to the predicted transport capacity given Current Conditions (2006). Results from the four individual equations were also used as a tool that allows each of the different transport capacity equations to be compared with observations of existing conditions. Numeric values from an individual equation were then be evaluated to see if results matched physical observations, allowing for the exclusion of specific equations as appropriate. Given the range of bedload transport predicted by the different equations, changes in the percent of bedload capacity were used to compare Project alternatives with RFFAs with Current Conditions (2006).

Annual sediment transport capacity calculations were completed for each equation by determining the mass of sediment capacity for each flow bin and multiplying this value by the flow frequency. At each site the sediment capacity for each flow bin is a constant while the flow frequency changes for the different Project alternatives. Total annual sediment transport capacity was calculated using each of the four transport equations and the BAGS and HEC-RAS models.

Phase 2 Sediment Transport

Sediment transport can be considered as having two phases. In Phase 1, sand and finer material is typically transported from within the channel bed armor with transport occurring at a relatively low rate. During this phase, transport is typically limited by sediment supply (Schmidt and Potyondy 2004). During Phase 2 transport, sediment transport transitions to a much higher rate and includes sands and coarse gravel as the channel bed itself is disrupted by flows. The purpose of the Phase 2 transport analysis is to define the flows where the bed of the channel is disrupted thus mobilizing the channel itself.

A Phase 2 sediment transport occurs when flows are great enough to mobilize the channel bed and transport bed sized particles. The onset of Phase 2 sediment transport is of particular interest in the EIS as this is the flow that is required to rejuvenate the channel bed and achieve channel maintenance objectives (Schmidt and Potyondy 2004). The flow needed to achieve Phase 2 transport, the frequency of this flow and the percentage of time that flows equal or exceed this threshold were computed. Recurrence intervals and the amount of time that flows required for Phase 2 transport are exceeded were compared with Current Conditions (2006) to quantify potential effects of the different Project alternatives with RFFAs.

Phase 2 transport was computed using the Parker and Wilcock and Crowe equations within the BAGS software. The critical sediment size for Phase 2 transport was taken as the D_{16} sized material from the surface gradation following the findings of Ryan (Ryan 2002). Curves were developed comparing transport rate verses flow rates for the range of particle sizes present based on site classification. The flow initiating Phase 2 transport was defined by inspection of the generated curve. The onset of Phase 2 transport was defined as the flow at which transport is predicted for the D_{16} sized particle.

5- and 10-Year Flood Events

Based on research by Ryan it is believed that maintaining infrequent, peak flood flows such as the 5- and 10-year flood may be critical to maintaining channel morphology (Ryan 1997). Ryan's research, which included streams in the study area, suggested that channel widths downstream of diversions are maintained if these less frequent, high magnitude flows are preserved.

The magnitudes of the 5- and 10-year flood events were calculated at each Representative site for all Project alternatives with RFFAs. Anticipated peak flood flow events were quantified. Predicted changes in frequency in the computed 5- and 10-year flow from Current Conditions (2006) were quantified to assess changes anticipated for the various Project alternatives with RFFAs. The maximum amount of time between a 5- and 10-year flow was determined to assess how changes in flow may impact time between these larger flow events.

Effective Discharge

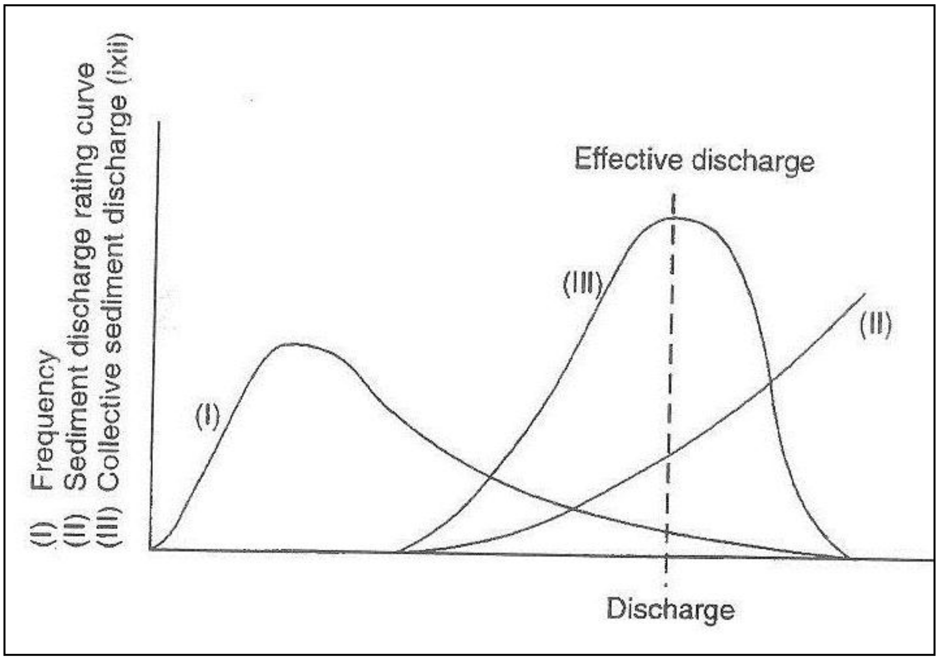
Effective discharge refers to the flow that transports the most sediment over a prolonged period of time. While higher flows transport more sediment, the infrequent occurrence of extreme events results in less sediment transported on average than somewhat more frequent, lower magnitude flows. Effective discharge is a representative flow that has the ability to transport the most bed material over a period of years. Computation of effective discharge is thus a useful tool in assessing the potential for geomorphic change due to alterations in stream flow regime. Particularly in sediment-limited systems, however, changes to effective discharge do not necessarily correspond to changes in channel morphology.

The procedure for determining effective discharge is designed to integrate the impacts of physical processes responsible for determining channel dimensions. This procedure was applied to the Project alternatives with RFFAs, where the hydrologic regime differs under each of the Project alternatives due to diversions or flow augmentations. The total amount of sediment transported by different flows was calculated by multiplying the frequency of occurrence of each flow by the median sediment load for that class. Figure 4.6.3-3 illustrates the derivation of the effective discharge. The flow rate that corresponds with the maximum sediment transport capacity is the effective discharge (see curve III in Figure 4.6.3-3). The area under the sediment discharge curve (curve III in Figure 4.6.3-3) is the total amount of sediment transported.

Effective discharge was determined for each Project alternative with RFFAs at each Representative site using each of the four sediment transport equations. Effective discharge calculations are typically not sensitive to the selection of a transport equation (Barry et al. 2006). A single effective discharge was selected based on the average of the four calculated flows.

An important component of effective discharge in evaluating potential impact on stream morphology is the recurrence interval associated with that flow rate. The recurrence interval of the calculated effective discharge value was determined using the previously described probability plots. Results of the Project alternatives with RFFAs were compared with Current Conditions (2006) to assess cumulative effects.

Figure 4.6.3-3
Effective Discharge Schematic



Source: Wolman, 1960.

4.6.3.6 Methods for Geomorphologic Impacts at Representative Sites

Anticipated impacts were quantified at the 16 Representative sites using the numeric approaches outlined above. Annual sediment transport capacity, the threshold for Phase 2 sediment transport, magnitude of peak flood events and effective discharge calculations were made for Project alternatives. Results are presented below with numeric values for all Project alternatives with RFFAs compared with Current Conditions (2006) to assess potential cumulative impacts.

4.6.3.6.1 Annual Sediment Transport Capacity

Annual bedload sediment transport capacity was determined at the Representative sites using the four transport equations. Calculations based on bedload exclude suspended sediment which typically comprises a majority of the total sediment transported. Results of annual bedload transport capacity are presented in Table 4.6.3-8. Figures showing transport capacity at the Representative sites are provided in Figures H-10.1 to H-10.16 in Appendix H-10. Transport capacity of all alternatives includes the alternative with RFFAs.

Table 4.6.3-8
Calculated Annual Bedload Transport Capacity (tons/year)

Site	Equation	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
FR1	Parker	207	180	152	84	87
	W-C	590	544	458	253	272
	Yang	6,074	5,497	4,957	3,496	3,591
	MPM	24,771	23,127	21,697	17,736	18,006
FR2	Parker	1,301	1,220	1,129	779	802
	W-C	1,792	1,674	1,561	1,037	1,060
	Yang	17,882	17,106	16,296	13,046	13,292
	MPM	64,024	61,520	59,142	51,077	51,996
FR3	Parker	1,191	1,133	1,078	734	763
	W-C	1,292	1,248	1,200	844	865
	Yang	1,431	1,363	1,293	965	1,002
	MPM	12,782	12,170	11,541	8,462	8,797
FR4	Parker	2,199	2,178	2,081	1,499	1,574
	W-C	1,443	1,440	1,406	1,177	1,204
	Yang	3,351	3,263	3,128	2,521	2,609
	MPM	181,428	177,150	173,027	156,028	159,025
FR5	Parker	281	252	222	128	132
	W-C	308	282	249	145	149
	Yang	680	606	526	292	306
	MPM	1,909	1,733	1,537	939	973
FR6	Parker	0	0	0	0	0
	W-C	1	1	1	0	0
	Yang	90	77	63	38	39
	MPM	1,683	1,466	1,242	772	793
FR7	Parker	132	142	154	216	202
	W-C	118	126	136	182	172
	Yang	3,037	3,176	3,250	3,515	3,469
	MPM	12,273	12,815	13,097	14,106	13,932
WF1	Parker	1,256	1,225	1,178	956	985
	W-C	4,699	4,617	4,497	3,911	3,979
	Yang	11,064	10,563	10,274	9,166	9,360
	MPM	27,945	26,705	26,054	23,572	24,018
WF2	Parker	1,434	1,396	1,341	1,077	1,116
	W-C	1,409	1,384	1,353	1,196	1,215
	Yang	5,714	5,302	5,078	4,211	4,357
	MPM	42,847	37,691	35,953	29,908	31,082

Table 4.6.3-8 (continued)
Calculated Annual Bedload Transport Capacity (tons/year)

Site	Equation	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
CR1	Parker	35	36	35	30	31
	W-C	48	50	48	42	43
	Yang	16,177	13,339	13,091	12,141	12,262
	MPM	71,835	60,717	60,039	57,346	57,740
CR2	Parker	521	576	547	492	508
	W-C	574	616	589	530	547
	Yang	7,416	6,662	6,494	6,014	6,073
	MPM	126,433	117,869	116,276	111,073	111,798
BR1	Parker	0	0	0	0	0
	W-C	1	0	0	0	0
	Yang	3,704	2,764	2,398	2,594	2,613
	MPM	122,878	91,783	79,887	86,041	86,618
NF1	Parker	17	52	68	92	91
	W-C	74	179	222	277	274
	Yang	33,472	41,562	44,584	44,417	44,300
	MPM	125,295	144,472	151,463	151,384	151,089
NF2	Parker	62	96	112	139	137
	W-C	233	401	472	569	562
	Yang	29,581	38,553	41,839	41,809	41,626
	MPM	56,006	73,340	79,567	80,300	79,938
SBC1	Parker	6	6	6	10	9
	W-C	12	12	13	20	20
	Yang	25,172	26,088	26,861	29,581	29,214
	MPM	186,622	187,714	189,486	197,204	196,282
SBC3	Parker	2,341	3,023	3,380	1,343	1,383
	W-C	304	374	417	178	183
	Yang	22,213	22,999	23,680	22,232	22,105
	MPM	488,464	506,938	517,575	573,402	569,868

Notes:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.
RFFA = reasonably foreseeable future action

Large disparities in the calculated bedload transport capacity utilizing the different equations illustrate significant uncertainty in defining actual capacity. The following conclusions can be drawn from the calculated transport results shown in Table 4.6.3-8:

The order of magnitude of transport capacity calculated using the Parker and Wilcock and Crowe equations are generally the same.

Transport capacity calculated using the Yang equation is typically an order of magnitude greater than that calculated using the Parker or Wilcock and Crowe equation.

Transport capacity calculated using the MPM equation is the largest, often exceeding values calculated using the Yang equation by an order of magnitude.

Transport capacity calculated using the Parker and Wilcock and Crowe equations often produce results which are unreasonably low and which contradict observed conditions. Extreme examples of this include BR1 where results indicate that the stream only has the capacity to move less than 2 ton per year of bedload, CR1 (< 50 tons per year [tpy]), NF1 (< 75 tpy) and SBC1 (<15 tpy). Were these results to be accurate, large amounts of sediment would be accumulating and bed deposition would have occurred, neither of which has been observed based on direct observation or results of aerial and gage data analysis. For these reasons results of the Parker and Wilcock and Crowe equations are believed to underestimate sediment transport for at least some locations.

Given the range of results obtained from this numeric analysis and the uncertainty associated with the sediment transport capacity predicted by any one equation, it is difficult to accurately predict the absolute sediment transport capacity value at the sites. It is, however, possible to use the numeric data to determine the relative change in calculated transport capacity as the percent change was generally found to be independent of the specific equation used. The percent change in annual transport capacity for each alternative with RFFAs was therefore calculated in relation to the capacity at Current Conditions (2006) and used as a means of quantifying potential impacts.

Percent change was determined for each of the four transport equations as the ratio of transport capacity for a given alternative with RFFAs to the transport capacity for Current Conditions (2006). The range, mean and standard deviation of the percent change from the different equations was also determined. This metric provides an indication of the change in transport capacity that is expected when Project alternatives with RFFAs are compared to Current Conditions (2006). Results are presented in Table 4.6.3-9 and discussed by watershed. Note that in the case of sites FR6 and BR1, the Parker and Wilcock and Crowe equations predicted that annual bedload transport capacity for Current Conditions (2006) was an unrealistic value of one ton per year or less. These values were excluded from the calculations as indicated in the table below.

As results below indicate, the four different equations typically predict similar percent change in annual sediment transport capacity. In case sites where the percentage change predicted by the different equations results in a wider range of values, the wide range is usually attributable to one or more equation predicting a very low annual transport capacity. Written descriptions of the percent change in sediment transport capacity are provided in the text and Table 4.6.3-9 and are based on the average of the results from the different equations.

Table 4.6.3-9
Calculated Annual Bedload Transport Capacity as a Percent of Current Conditions

Site	Equation	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
FR1	Parker	100%	87%	73%	41%	42%
	W-C	100%	92%	78%	43%	46%
	Yang	100%	91%	82%	58%	59%
	MPM	100%	93%	88%	72%	73%
	Range	N/A	87% - 93%	73% - 88%	41% - 72%	42% - 73%
	Average	N/A	91%	80%	53%	55%
	St. Dev.	N/A	3%	6%	14%	14%
FR2	Parker	100%	94%	87%	60%	62%
	W-C	100%	93%	87%	58%	59%
	Yang	100%	96%	91%	73%	74%
	MPM	100%	96%	92%	80%	81%
	Range	N/A	93% - 96%	87% - 92%	58% - 80%	59% - 81%
	Average	N/A	95%	89%	68%	69%
	St. Dev.	N/A	1%	3%	11%	10%
FR3	Parker	100%	95%	91%	62%	64%
	W-C	100%	97%	93%	65%	67%
	Yang	100%	95%	90%	67%	70%
	MPM	100%	95%	90%	66%	69%
	Range	N/A	95% - 97%	90% - 93%	62% - 67%	64% - 70%
	Average	N/A	96%	91%	65%	67%
	St. Dev.	N/A	1%	1%	3%	3%
FR4	Parker	100%	99%	95%	68%	72%
	W-C	100%	100%	97%	82%	83%
	Yang	100%	97%	93%	75%	78%
	MPM	100%	98%	95%	86%	88%
	Range	N/A	97% - 100%	93% - 97%	68% - 86%	72% - 88%
	Average	N/A	98%	95%	78%	80%
	St. Dev.	N/A	1%	2%	8%	7%
FR5	Parker	100%	90%	79%	46%	47%
	W-C	100%	92%	81%	47%	48%
	Yang	100%	89%	77%	43%	45%
	MPM	100%	91%	81%	49%	51%
	Range	N/A	89% - 92%	77% - 81%	43% - 49%	45% - 51%
	Average	N/A	90%	79%	46%	48%
	St. Dev.	N/A	1%	2%	3%	3%

Table 4.6.3-9 (continued)
Calculated Annual Bedload Transport Capacity as a Percent of Current Conditions

Site	Equation	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
FR6	Parker	Excluded	Excluded	Excluded	Excluded	Excluded
	W-C	Excluded	Excluded	Excluded	Excluded	Excluded
	Yang	100%	86%	70%	42%	43%
	MPM	100%	87%	74%	46%	47%
	Range	N/A	86% - 87%	70% - 74%	42% - 46%	43% - 47%
	Average	N/A	87%	72%	44%	45%
	St. Dev.	N/A	1%	3%	3%	3%
FR7	Parker	100%	108%	117%	164%	153%
	W-C	100%	107%	115%	154%	146%
	Yang	100%	105%	107%	116%	114%
	MPM	100%	104%	107%	115%	114%
	Range	N/A	104% - 108%	107% - 117%	115% - 164%	114% - 153%
	Average	N/A	106%	111%	137%	132%
	St. Dev.	N/A	2%	5%	25%	21%
WF1	Parker	100%	98%	94%	76%	78%
	W-C	100%	98%	96%	83%	85%
	Yang	100%	95%	93%	83%	85%
	MPM	100%	96%	93%	84%	86%
	Range	N/A	95% - 98%	93% - 96%	76% - 84%	78% - 86%
	Average	N/A	97%	94%	82%	83%
	St. Dev.	N/A	1%	1%	4%	3%
WF2	Parker	100%	97%	94%	75%	78%
	W-C	100%	98%	96%	85%	86%
	Yang	100%	93%	89%	74%	76%
	MPM	100%	88%	84%	70%	73%
	Range	N/A	88% - 98%	84% - 96%	70% - 85%	73% - 86%
	Average	N/A	94%	91%	76%	78%
	St. Dev.	N/A	5%	5%	6%	6%
CR1	Parker	100%	103%	100%	86%	89%
	W-C	100%	104%	100%	88%	90%
	Yang	100%	82%	81%	75%	76%
	MPM	100%	85%	84%	80%	80%
	Range	N/A	82% - 104%	81% - 100%	75% - 88%	76% - 90%
	Average	N/A	94%	91%	82%	84%
	St. Dev.	N/A	12%	10%	6%	7%

Table 4.6.3-9 (continued)
Calculated Annual Bedload Transport Capacity as a Percent of Current Conditions

Site	Equation	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
CR2	Parker	100%	111%	105%	94%	98%
	W-C	100%	107%	103%	92%	95%
	Yang	100%	90%	88%	81%	82%
	MPM	100%	93%	92%	88%	88%
	Range	N/A	90% - 111%	88% - 105%	81% - 94%	82% - 98%
	Average	N/A	100%	97%	89%	91%
	St. Dev.	N/A	10%	8%	6%	7%
BR1	Parker	Excluded	Excluded	Excluded	Excluded	Excluded
	W-C	Excluded	Excluded	Excluded	Excluded	Excluded
	Yang	100%	75%	65%	70%	71%
	MPM	100%	75%	65%	70%	70%
	Range	N/A	75% - 75%	65% - 65%	70% - 70%	70% - 71%
	Average	N/A	75%	65%	70%	71%
	St. Dev.	N/A	0%	0%	0%	1%
NF1	Parker	100%	306%	400%	541%	535%
	W-C	100%	242%	300%	374%	370%
	Yang	100%	124%	133%	133%	132%
	MPM	100%	115%	121%	121%	121%
	Range	N/A	115% - 306%	121% - 400%	121% - 541%	121% - 535%
	Average	N/A	197%	239%	292%	290%
	St. Dev.	N/A	93%	135%	203%	200%
NF2	Parker	100%	155%	181%	224%	221%
	W-C	100%	172%	203%	244%	241%
	Yang	100%	130%	141%	141%	141%
	MPM	100%	131%	142%	143%	143%
	Range	N/A	130% - 172%	141% - 203%	141% - 244%	141% - 241%
	Average	N/A	147%	167%	188%	186%
	St. Dev.	N/A	20%	30%	54%	52%
SBC1	Parker	100%	100%	100%	167%	150%
	W-C	100%	100%	108%	167%	167%
	Yang	100%	104%	107%	118%	116%
	MPM	100%	101%	102%	106%	105%
	Range	N/A	100% - 104%	100% - 108%	106% - 167%	105% - 167%
	Average	N/A	101%	104%	139%	134%
	St. Dev.	N/A	2%	4%	32%	29%

Table 4.6.3-9 (continued)
Calculated Annual Bedload Transport Capacity as a Percent of Current Conditions

Site	Equation	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
SBC3	Parker	100%	129%	144%	57%	59%
	W-C	100%	123%	137%	59%	60%
	Yang	100%	104%	107%	100%	100%
	MPM	100%	104%	106%	117%	117%
	Range	N/A	104% - 129%	106% - 144%	57% - 117%	59% - 117%
	Average	N/A	115%	124%	83%	84%
	St. Dev.	N/A	13%	20%	30%	29%

Notes:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.
N/A = not applicable

Fraser River Basin

Results indicate that with the exception of Vasquez Creek (FR7), bedload transport capacity given the Project alternatives with RFFAs will generally decrease at all sites in the Fraser River Basin when compared to Current Conditions (2006). Capacities will generally decrease by the greatest percentage at locations in closest proximity to diversions and nearest the main stem of the Fraser River (FR1, FR5, and FR6). Reductions in bedload transport capacity are predicted to be less dramatic on tributary streams further downstream of Winter Park as evidenced by predicted capacity reductions on Ranch Creek (FR4) and St. Louis Creek (FR3) relative to predicted reductions on the Fraser River (FR1 and FR5) and Jim Creek (FR6). Capacities in Vasquez Creek are predicted to increase at the FR7 site as this is a location where additional flow is added to the system from diversions in the Williams Fork River. Denver Water's operation of the Moffat Collection System, where more water is taken from diversions closest to the Moffat Tunnel, results in these areas having the greatest flow and transport capacity reductions. Bedload transport capacity figures for Representative sites in the Fraser River Basin are presented in Figures H-10.1 to H-10.7 in Appendix H-10.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change in transport capacity when compared to Current Conditions (2006). Given Full Use of the Existing System, calculated transport capacity at FR1 and FR5 are predicted to decrease by approximately 10% based on the average of the four transport equations. Capacity in Jim Creek (FR6) is calculated to decrease by 14% while the capacity in Vasquez Creek above Denver Water's diversion (FR7) is predicted to increase by 6%. Transport capacities at all other sites are predicted to decrease by no more than 5% based on the average of the four transport equations.

The No Action Alternative is expected to produce the next smallest change in bedload transport. Calculated transport capacities at FR1 and FR5 are predicted to decrease by approximately 20%, and FR6 is predicted to decrease by approximately 28% when compared to Current Conditions (2006). Capacities at FR2, FR3, and FR4 are predicted to decrease by approximately 5%-10%. The capacity in Vasquez Creek above the diversion is predicted to increase by 11% based on the average of the four transport equations.

Bedload transport capacity reductions resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be the greatest of the alternatives. Calculated capacities at FR1, FR5, and FR6 are predicted to decrease by approximately 45%-55% when compared to Current Conditions (2006). Capacities at FR2, FR3, and FR4 are predicted to decrease by approximately 20%-35%. The capacity in Vasquez Creek above the diversion is predicted to increase by approximately 35% based on the average of the four transport equations.

Williams Fork River Basin

Results indicate that bedload transport capacity would decrease in the Williams Fork for all Project alternatives with RFFAs when compared to Current Conditions (2006). Capacities will decrease by the greatest percentage higher in the basin (WF2) than lower (WF1). This is due to inflows from additional tributaries muting flow and transport capacity reductions further downstream. Bedload transport capacity figures for Representative sites in the Williams Fork River Basin are presented in Figures H-10.8 and H-10.9 in Appendix H-10.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change to transport capacity. Given Full Use of the Existing System, calculated transport capacity at WF1 and WF2 are predicted to decrease by approximately 3% and 6%, respectively when compared to Current Conditions (2006). The No Action Alternative is expected to produce the next smallest change in bedload transport. Calculated transport capacities at WF1 and WF2 are predicted to decrease by 6% and 9% when compared to Current Conditions (2006) based on the average of the four transport equations. Bedload transport capacity reductions resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be the greatest of the alternatives. Calculated capacity at WF1 is predicted to decrease by approximately 18% when compared to Current Conditions (2006); transport capacity at WF2 is predicted to decrease by approximately 23% based on the average of the four transport equations.

Colorado River Basin

Results indicate that bedload transport capacity would decrease in the Colorado River when compared to Current Conditions (2006). Capacities would decrease by the greatest percentage higher in the basin (CR1) than lower (CR2). The Williams Fork enters the Colorado River between CR1 and CR2, with additional inflows from the Williams Fork reducing changes to the existing flows and bedload transport capacity. Bedload transport capacity figures for Representative sites in the Colorado River are presented in Figures H-10.10 and H-10.11 in Appendix H-10.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change to transport capacity when compared to Current Conditions (2006). Given Full Use of the Existing System, calculated transport capacity at CR1 is predicted to be reduced by 6% based on the average of the four transport equations while no change in transport capacity is predicted at CR2. The No Action Alternative is expected to produce the next smallest change in bedload transport. Calculated transport capacities at

CR1 and CR2 are predicted to decrease by 9% and 3%, respectively when compared to Current Conditions (2006). Bedload transport capacity reductions resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be the greatest of the alternatives. Calculated capacities at CR1 are predicted to decrease by approximately 16% when compared to Current Conditions (2006); transport capacity at CR2 is predicted to decrease by approximately 9% based on the average of the four transport equations.

Blue River Basin

Results indicate that bedload transport capacity given the different Project alternatives with RFFAs would be reduced in the Blue River when compared to Current Conditions (2006) as the result of lower flows. When comparing the different alternatives with RFFAs, Full Use of the Existing System, the Proposed Action and Alternative 8a with RFFAs are predicted to change capacity by similar percentages. When compared to Current Conditions (2006), each of these alternatives is predicted to reduce bedload transport capacity by approximately 20% to 30% based on the average of the four transport equations. The No Action Alternative is expected to produce the greatest change in bedload transport with a decrease of approximately 35% when compared to Current Conditions (2006). Bedload transport capacity figures for the Representative site in the Blue River is presented in Figure H-10.12 in Appendix H-10.

North Fork South Platte River Basin

Results indicate that bedload transport capacity would increase in the North Fork when compared to Current Conditions (2006). Capacities would increase by the greatest percentage higher in the basin (NF1) than lower (NF2). This is due to inflows from additional tributaries muting flow augmentation further downstream. Bedload transport capacity figures for Representative sites in the North Fork South Platte are presented in Figures H-10.13 and H-10.14 in Appendix H-10.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change to transport capacity when compared to Current Conditions (2006). Given Full Use of the Existing System, calculated transport capacity at NF1 and NF2 are predicted to increase by approximately 100% and 50%, respectively, based on the average of the four transport equations. The No Action Alternative is expected to produce the next smallest change in bedload transport. Calculated transport capacities at NF1 and NF2 are predicted to increase by approximately 140% and 70% when compared to Current Conditions (2006). Bedload transport capacity increases resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar at NF1 and are predicted to increase by approximately 195% when compared to Current Conditions (2006); transport capacity at NF2 is predicted to increase by approximately 90%.

South Boulder Creek Basin

Results indicate that bedload transport capacity will generally increase for the Project alternatives with RFFAs in South Boulder Creek when compared to Current Conditions (2006); however decreases are expected below Gross Reservoir for some alternatives. Capacities below Gross Reservoir (SBC3) are predicted to increase for Full Use of the

Existing System and the No Action Alternative and decrease, given the Proposed Action and Alternative 8a. Decreases in capacities for these alternatives are the result of the way releases from the reservoir would be managed. Given the Proposed Action and Alternative 8a, reservoir releases would increase during low flow periods and decrease during peak flow months when compared to Current Conditions (2006). A reduction in releases during peak months, when the majority of bedload transport occurs, is the cause of the decrease in transport capacity. Bedload transport capacity figures for Representative sites in South Boulder Creek are presented in Figures H-10.15 and H-10.16 in Appendix H-10.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change to transport capacity when compared to Current Conditions (2006) both upstream and downstream of the reservoir. Given Full Use of the Existing System, calculated transport capacity at SBC1 is predicted to increase by 4% while capacity at SBC3 is predicted to increase by 15% based on the average of the four transport equations. Given the No Action Alternative, transport capacities are expected to increase by 9% and 24% at SBC1 and SBC3. Bedload transport capacity increases at SBC1 resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be approximately 40%. Calculated capacities at SBC3 downstream of the reservoir are predicted to decrease by approximately 16% when compared to Current Conditions (2006) given the predicted release patterns.

Overall Bedload Transport Capacity Trends

Calculated bedload transport capacities follow anticipated trends. Capacities are predicted to be reduced the most in areas where flow reductions are greatest and increased the most in areas with the largest increase in flows. Typically changes in transport capacity are greatest given the Proposed Action and Alternative 8a and least for Full Use of the Existing System.

As discussed below, bedload sediment is in large part supplied from the channel bed and banks themselves during higher flow events. Decreases in flows predicted at different locations for the different Project alternatives therefore reduce both bedload supply and transport capacity. Similarly areas where flows and transport capacity increases are predicted will also have increases in bedload sediment supply.

4.6.3.7 Sediment Supply

The bedload component of sediment supply is largely derived from sediment from within the channel that is mobilized in response to larger flow events. Changes in flow resulting from the different Project alternatives will therefore change bedload sediment in the streams. Changes in sediment transport were estimated using the supply equations presented for the Representative sites and the predicted flow durations data of the various alternatives. Changes in supply within the different basins are presented in this section. Table 4.6.3-10 shows calculated sediment supply at the Representative sites for the various Project alternatives with RFFAs. Changes in sediment supply for each alternative as a percent of Current Conditions (2006) is given in Table 4.6.3-11. Sediment supply curves for the Project alternatives are provided in Figures H-10.1 to H-10.16 in Appendix H-10.

Table 4.6.3-10
Calculated Annual Sediment Supply (tons/year)

Site	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
FR1	266	246	226	173	177
FR2	3,361	3,251	3,162	2,850	2,887
FR3	508	493	477	415	423
FR4	127	124	119	99	102
FR5	161	147	134	95	98
FR6	32	29	25	18	18
FR7	913	946	962	1,023	1,012
WF1	608	585	569	503	514
WF2	75	68	65	53	53
CR1	6,917	5,915	5,832	5,509	5,551
CR2	11,487	10,884	10,769	10,684	10,441
BR1	1,251	1,063	996	1,031	1,034
NF1	5,758	7,586	8,269	8,200	8,174
NF2	6,110	8,911	9,967	10,704	10,621
SBC1	3,351	3,476	3,582	3,958	3,907
SBC3	4,389	4,504	4,609	4,705	4,676

Notes:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.
RFFA = reasonably foreseeable future action

Table 4.6.3-11
Calculated Sediment Supply as Percent of Current Conditions (2006)

Site	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
FR1	100%	92%	85%	65%	66%
FR2	100%	97%	94%	85%	86%
FR3	100%	97%	94%	82%	83%
FR4	100%	97%	94%	78%	81%
FR5	100%	91%	83%	59%	61%
FR6	100%	90%	77%	54%	55%
FR7	100%	104%	105%	112%	111%
WF1	100%	96%	93%	83%	84%
WF2	100%	90%	86%	71%	74%
CR1	100%	86%	84%	80%	80%
CR2	100%	95%	94%	90%	91%

Table 4.6.3-11 (continued)
Calculated Sediment Supply as Percent of Current Conditions (2006)

Site	Current Conditions (2006)	Full Use of the Existing System	No Action Alternative	Proposed Action with RFFAs	Alternative 8a with RFFAs
BR1	100%	85%	80%	82%	83%
NF1	100%	132%	144%	142%	142%
NF2	100%	146%	163%	175%	174%
SBC1	100%	104%	107%	118%	117%
SBC3	100%	103%	105%	107%	107%

Notes:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.
RFFA = reasonably foreseeable future action

Fraser River Basin

Results indicate that with the exception of Vasquez Creek (FR7), sediment supply is predicted to decrease at all Representative sites for all Project alternatives with RFFAs when compared to Current Conditions (2006). Similar to bedload transport capacity, supply will decrease by the greatest percentage at locations in closest proximity to diversions and nearest the main stem of the Fraser River (FR1, FR5, and FR6). Reductions in supply are predicted to be less dramatic on tributary streams further downstream of Winter Park as evidenced by supply reductions on Ranch Creek (FR4) and St. Louis Creek (FR3) relative to predicted reductions on the Fraser River (FR1 and FR5) and Jim Creek (FR6). Supply in Vasquez Creek is predicted to increase at the FR7 site as this is a location where additional flow is added to the system from diversions in the Williams Fork.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change in supply when compared to Current Conditions (2006). Given Full Use of the Existing System, calculated supply at FR1, FR5, and FR6 are predicted to decrease by approximately 8%-10%. Supply in Vasquez Creek above Denver's Diversion (FR7) is predicted to increase by 4%. Supply at all other sites is predicted to decrease by no more than 3%.

The No Action Alternative is expected to produce the next smallest change in sediment supply. Supply at FR1, FR5, and FR6 are predicted to decrease by approximately 15-23% when compared to Current Conditions (2006). Supply at FR2, FR3, and FR4 are predicted to decrease by approximately 6%. The supply in Vasquez Creek above the diversion is predicted to increase by 5%.

Sediment supply reductions resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be the greatest of the alternatives. Calculated capacities at FR1, FR5, and FR6 are predicted to decrease by approximately 34%-46% when compared to Current Conditions (2006). Capacities at FR2, FR3, and FR4 are predicted to decrease by approximately 14% -22%. The capacity in Vasquez Creek above the diversion is predicted to increase by approximately 11%-2%.

Williams Fork River Basin

Results indicate that sediment supply will decrease in the Williams Fork for all Project alternatives with RFFAs when compared to Current Conditions (2006). Supply will decrease by the greatest percentage higher in the basin (WF2) than lower (WF1). This is due to inflows from additional tributaries muting flow and sediment supply reductions further downstream.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change in sediment supply. Given Full Use of the Existing System, calculated supply at WF1 and WF2 are predicted to decrease by approximately 4% and 10%, respectively when compared to Current Conditions (2006). The No Action Alternative is expected to produce the next smallest change in sediment supply. Calculated supply at WF1 and WF2 are predicted to decrease by 7% and 14% when compared to Current Conditions (2006). Sediment supply reductions resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be the greatest of the alternatives. Calculated supply at WF1 is predicted to decrease by approximately 16% when compared to Current Conditions (2006); supply at WF2 is predicted to decrease by approximately 26%-29%.

Colorado River Basin

Results indicate that sediment supply will decrease in the Colorado River when compared to Current Conditions (2006). Supply will decrease by the greatest percentage higher in the basin (CR1) than lower (CR2). The Williams Fork enters the Colorado River between CR1 and CR2, with additional inflows from the Williams Fork reducing changes to the existing flows and sediment supply.

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change in sediment supply when compared to Current Conditions (2006). Given Full Use of the Existing System, calculated supply at CR1 is predicted to be reduced by 14% while a decrease of 5% is predicted at CR2. The No Action Alternative is expected to produce the next smallest change in sediment supply. Calculated supply at CR1 and CR2 are predicted to decrease by 16% and 6%, respectively when compared to Current Conditions (2006). Sediment supply reductions resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be the greatest of the alternatives. Calculated supply at CR1 is predicted to decrease by approximately 20% when compared to Current Conditions (2006); supply at CR2 is predicted to decrease by approximately 10%.

Blue River Basin

Results indicate that sediment supply given the different Project alternatives with RFFAs will be reduced in the Blue River when compared to Current Conditions (2006) as the result of lower flows. When comparing the different alternatives, Full Use of the Existing System, the Proposed Action and Alternative 8a with RFFAs are predicted to change sediment supply by similar percentages. When compared to Current Conditions (2006), each of these alternatives is predicted to reduce supply by approximately 15%-20%. The

No Action Alternative is expected to produce the greatest change in supply with a decrease of approximately 20% when compared to Current Conditions (2006).

North Fork South Platte River Basin

Results indicate that sediment supply will increase in the North Fork when compared to Current Conditions (2006). Supply is predicted to increase by the greatest percentage lower in the basin (NF2) rather than higher (NF1).

When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change to sediment supply when compared to Current Conditions (2006). Given Full Use of the Existing System, calculated supply at NF1 and NF2 are predicted to increase by approximately 32% and 46%, respectively. The No Action Alternative is expected to produce the next smallest change in supply. Calculated sediment supply at NF1 and NF2 are predicted to increase by approximately 44% and 63% when compared to Current Conditions (2006). Sediment supply increases resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar at NF1 and are predicted to increase by approximately 42% when compared to Current Conditions (2006); supply at NF2 is predicted to increase by approximately 75%.

South Boulder Creek Basin

Results indicate sediment supply will increase in South Boulder Creek when compared to Current Conditions (2006). When comparing the different alternatives with RFFAs, Full Use of the Existing System results in the smallest change to sediment supply when compared to Current Conditions (2006) both upstream and downstream of the reservoir. Given Full Use of the Existing System, calculated supply at SBC1 is predicted to increase by 4% while supply at SBC3 is predicted to increase by 3%. Given the No Action Alternative, sediment supply is expected to increase by 7% and 5% at SBC1 and SBC3. Sediment supply increases at SBC1 resulting from the Proposed Action and Alternative 8a with RFFAs are generally similar and predicted to be approximately 17%-18%. Calculated supply at SBC3 downstream of the reservoir is predicted to increase by approximately 7% when compared to Current Conditions (2006).

Overall Sediment Supply Trends

Calculated sediment supply follows anticipated trends. Supply is predicted to be reduced the most in areas where flow reductions are greatest and increased the most in areas with the largest increase in flows. Typically changes in sediment supply are greatest given the Proposed Action and Alternative 8a with RFFAs and least for Full Use of the Existing System. Trends anticipated in sediment supply generally mimic predicted changes in bedload transport capacity as both are influenced by flow changes in the same way.

Sediment Supply Sensitivity Analysis

A sensitivity analysis was completed comparing supply estimated using the general equation developed from the Two Forks sampling data and used for the Moffat EIS with data collected by the USFS on St. Louis Creek. The analysis was completed by comparing predicted sediment supply estimated using both the general equation used for the Final EIS and the 3rd order polynomial that was fit to the data collected by the USFS. The comparison was completed for Representative Site FR3, located on St. Louis Creek. This comparison allowed the general equation to be compared to observed data.

The general equation predicts sediment supply of 508 tpy at FR3 based on Current Conditions (2006). Using the curve generated from the site specific sampling, annual sediment supply was calculated to be 401 tpy. The value calculated using site specific sampling was 79% of the value using the general equation. For Full Use of the Existing System the general equation predicts a supply of 493 tpy. A value of 386 tpy was calculated using site specific data, which is 78% of that predicted by the general equation. For the No Action Alternative the general equation predicts a supply of 477 tpy. A value of 371 tpy was calculated using site specific data, which is also 78% of that predicted by the general equation. Given the Proposed Action and Alternative 8a with RFFAs, sediment supply predicted using the site specific data is 67% of the value predicted from the general equation. The Proposed Action with RFFAs is predicted to have a supply of 415 tpy using the general equation and 277 tpy using the site specific curve. For Alternative 8a, sediment supply is predicted to be 423 tpy using the general equation and 285 tpy based on the site specific data.

Results from the site specific data and the general equation were found to compare very well, with the site specific data indicating the general equation over predicted supply by roughly 30%. Given the large variability noted when estimating transport capacity, results for supply were determined to be very similar providing confidence that sediment supply estimates prepared as part of this EIS are reasonable.

4.6.3.8 Phase 2 Sediment Transport

The magnitude of flow required for the onset of Phase 2 sediment transport was determined at each Representative site. The required flow is a function of channel geometry and bed gradations and is not dependent on flow frequency, therefore the flow required to initiate Phase 2 transport is the same for all alternatives. The recurrence interval, percent of the time flows equal or exceed the Phase 2 flow and maximum number of years between flow events large enough to cause Phase 2 transport were calculated based on the hydrology anticipated for each alternative (with RFFAs) using daily PACSM data. Results for the various alternatives were compared with results obtained for Current Conditions (2006) to assess how flow alternations will change the frequency and duration of Phase 2 transport.

Tables below present results calculated at the Representative sites in each basin. Tabulated values include results calculated using both the Parker equation and the Wilcock and Crowe equation. Values in the text comparing results at the different sites and for the different alternatives are based on the average value derived from the Parker and Wilcock and Crowe equations. Figures showing transport for various flows and particle sizes are provided in Figures H-21.1 to H-21.32 in Appendix H-21.

Fraser River Basin

Flows required to initiate Phase 2 sediment transport were calculated for the Representative sites in the Fraser River for the Project alternatives with RFFAs based on the measured D_{16} material size observed at each of the sites. The calculated flow along with the recurrence interval, flow frequency and maximum number of years between Phase 2 flows were calculated and are presented below. Calculated values are presented on Table 4.6.3-12. Figures showing Phase 2 modeling results in the Fraser River Basin are presented in Figures H-21.1 to H-21.14 in Appendix H-21.

Table 4.6.3-12
Phase 2 Sediment Transport Calculations – Fraser River Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/W-C)	Maximum Duration Between Phase 2 Flows (yrs) (Parker/W-C)
FR1	4 (fine gravel)	123 / 75	Current Conditions	1.8 / 1.8	2.2% / 3.1%	5 / 5
			Full Use	1.9 / 1.8	1.8% / 2.7%	5 / 5
			No Action	2.1 / 1.8	1.6% / 2.2%	7 / 5
			Proposed Action with RFFAs	3.1 / 2.2	0.8% / 1.1%	8 / 6
			Alt. 8a with RFFAs	2.8 / 2.0	0.9% / 1.2%	8 / 6
FR2	12 (medium gravel)	417 / 337	Current Conditions	1.4 / 1.3	6.3% / 8.3%	2 / 2
			Full Use	1.5 / 1.3	6.0% / 8.0%	2 / 2
			No Action	1.5 / 1.3	5.7% / 7.7%	2 / 2
			Proposed Action with RFFAs	1.6 / 1.4	4.5% / 6.7%	3 / 2
			Alt. 8a with RFFAs	1.6 / 1.4	4.7% / 6.9%	3 / 2
FR3	11 (medium gravel)	81 / 69	Current Conditions	1.4 / 1.3	6.1% / 6.6%	3 / 2
			Full Use	1.4 / 1.4	5.8% / 6.2%	3 / 2
			No Action	1.5 / 1.4	5.4% / 5.8%	3 / 2
			Proposed Action with RFFAs	1.6 / 1.5	3.9% / 4.5%	3 / 3
			Alt. 8a with RFFAs	1.6 / 1.5	4.2% / 4.7%	3 / 3
FR4	12 (medium gravel)	31 / 34	Current Conditions	1.3 / 1.3	5.7% / 5.3%	2 / 2
			Full Use	1.3 / 1.3	5.5% / 5.2%	2 / 2
			No Action	1.3 / 1.3	5.1% / 4.9%	2 / 2
			Proposed Action with RFFAs	1.4 / 1.4	3.7% / 3.5%	3 / 3
			Alt. 8a with RFFAs	1.4 / 1.4	3.9% / 3.7%	3 / 3

Table 4.6.3-12 (continued)
Phase 2 Sediment Transport Calculations – Fraser River Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/W-C)	Maximum Duration Between Phase 2 Flows (yrs) (Parker/W-C)
FR5	14 (medium gravel)	87 / 67	Current Conditions	1.8 / 1.8	2.5% / 2.9%	5 / 5
			Full Use	1.8 / 1.8	2.2% / 2.5%	5 / 5
			No Action	1.8 / 1.8	1.8% / 2.1%	5 / 5
			Proposed Action with RFFAs	2.6 / 2.6	1.0% / 1.1%	8 / 6
			Alt. 8a with RFFAs	2.6 / 2.6	1.0% / 1.2%	8 / 6
FR6	22 (coarse gravel)	112 / 91	Current Conditions	38 / 11	0.02% / 0.09%	36 / 20
			Full Use	34 / 9	0.01% / 0.12%	36 / 15
			No Action	36 / 11	0.01% / 0.10%	36 / 25
			Proposed Action with RFFAs	40 / 14	0.01% / 0.07%	36 / 26
			Alt. 8a with RFFAs	40 / 14	0.01% / 0.07%	36 / 26
FR7	19 (coarse gravel)	183 / 142	Current Conditions	1.2 / 1.1	3.0% / 5.8%	2 / 1
			Full Use	1.2 / 1.1	3.1% / 6.1%	1 / 1
			No Action	1.2 / 1.1	3.4% / 6.4%	1 / 1
			Proposed Action with RFFAs	1.1 / 1.1	4.7% / 7.9%	1 / 1
			Alt. 8a with RFFAs	1.1 / 1.1	4.5% / 7.7%	1 / 1

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Results indicate that the seven Representative sites can be considered as three different groups when describing the relative frequency of Phase 2 transport. One group includes sites FR2, FR3, FR4, and FR7. These sites include a site downstream on the main stem of the Fraser River (FR2), sites on St. Louis Creek (FR3) and Ranch Creek (FR4) downstream of Denver Water's diversions and one site on Vasquez Creek upstream Denver Water's diversion (FR7). At all of these locations Phase 2 transport is predicted to occur at a recurrence interval between approximately 1.1 and 1.6 years for Current Conditions (2006) and all alternatives with RFFAs. In all cases flow changes resulting from the various alternatives will change the recurrence interval of Phase 2 transport by no more than 0.2 year when compared to Current Conditions (2006). The frequency of flows equal to or exceeding that required to initiate Phase 2 transport is predicted to decrease at FR2, FR3, and FR4 and increase at FR7. At FR2, FR3, and FR4 Phase 2 transport is predicted to occur an average of at least a minimum of 13 days per year. Phase 2 transport is expected to occur a maximum of 23 days per year for all alternatives at FR7. The maximum number of years between flows large enough to produce Phase 2 sediment transport at each of these sites remains similar for all alternatives based on daily PACSM results. At each site and for all alternatives the greatest change predicted is one year or less.

The second group includes the Representative sites downstream of Denver Water's diversion on the Fraser River (FR1 and FR5). At both of these sites Phase 2 transport occurs with a recurrence interval of approximately 1.8 years given Current Conditions (2006). Given the Full Use of the Existing System and No Action Alternative with RFFAs, little to no change in the Phase 2 recurrence interval is anticipated. The Proposed Action and Alternative 8a are predicted to increase the recurrence interval of Phase 2 by approximately 0.5 year at these locations.

The frequency of flows equal to or exceeding that required to initiate Phase 2 transport is predicted to decrease at both FR1 and FR5 for all alternatives with RFFAs when compared to Current Conditions (2006). Currently, Phase 2 transport is predicted to occur approximately 10 days per year at these two locations. For Full Use of the Existing System and the No Action Alternative, Phase 2 transport is predicted to occur an average of 8 days and 7 days per year, respectively. Given the Proposed Action and Alternative 8a, Phase 2 transport is predicted to occur an average of approximately 3-4 days per year at these two sites. The maximum number of years between flows large enough to produce Phase 2 sediment transport at both of these sites is approximately 5 years for Current Conditions (2006). No change is predicted given Full Use of the Existing System. The No Action Alternative is not predicted to result any changes at FR5 while the maximum duration between events is predicted to increase to 6 years at FR1. Given the Proposed Action and Alternative 8a, the maximum interval between Phase 2 events is predicted to increase to approximately 7 years at both sites.

Site FR6, which is located downstream of the Jim Creek Diversion, is dissimilar to the other sites in that Phase 2 transport is predicted to occur very infrequently. For Current Conditions, Phase 2 transport is predicted have a recurrence interval of approximately 25 years. For Full Use of the Existing System the recurrence is predicted to be somewhat more frequent with an average recurrence interval of approximately 22 years. The recurrence interval for the No Action Alternative with RFFAs is approximately 24 years, while the calculated recurrence interval for the Proposed Action and Alternative 8a with RFFAs are approximately 27 years.

Phase 2 transport is not expected to occur often at this site given Current Conditions (2006) or any alternative. On average it is predicted that Phase 2 transport only occurs an average of approximately 0.2 days per year; this is not expected to change significantly for any alternative. The maximum number of years between Phase 2 events is predicted to range between approximately 25 and 30 years for Current Conditions (2006) and all alternatives.

Williams Fork River Basin

Flows required to initiate Phase 2 sediment transport were calculated for the Representative sites in the Williams Fork for the Project alternatives with RFFAs based on the measured D_{16} material size observed at each of the sites. The calculated flow along with the recurrence interval, flow frequency and maximum number of years between Phase 2 flows were calculated and are presented on Table 4.6.3-13. Figures showing Phase 2 modeling results in the Williams Fork River Basin are presented in Figures H-21.15 to H-21.18 in Appendix H-21.

Table 4.6.3-13
Phase 2 Sediment Transport Calculations – Williams Fork River Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/ W-C)	Maximum Duration between Phase 2 Flows (yrs) (Parker/ W-C)
WF1	6 (fine gravel)	105 / 70	Current Conditions	1.1 / 1.1	7.5% / 10.4%	2 / 2
			Full Use	1.1 / 1.1	7.3% / 9.6%	2 / 2
			No Action	1.2 / 1.1	6.9% / 9.2%	2 / 2
			Proposed Action with RFFAs	1.2 / 1.1	5.8% / 8.4%	2 / 2
			Alt. 8a with RFFAs	1.2 / 1.1	6.0% / 8.7%	2 / 2
WF2	10 (medium gravel)	65 / 60	Current Conditions	1.2 / 1.2	7.1% / 7.3%	2 / 2
			Full Use	1.2 / 1.2	6.8% / 7.0%	2 / 2
			No Action	1.2 / 1.2	6.4% / 6.5%	2 / 2
			Proposed Action with RFFAs	1.3 / 1.3	4.9% / 5.0%	2 / 2
			Alt. 8a with RFFAs	1.3 / 1.3	5.1% / 5.2%	2 / 2

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Calculated flows required to initiate Phase 2 sediment transport are predicted to increase from upstream to downstream in the basin. Results for recurrence intervals and frequency are similar for the two Representative sites. At both locations Phase 2 transport is predicted to occur at a recurrence interval of approximately 1.1-1.2 years for Current Conditions (2006). For all Project alternatives with RFFAs, predicted flow changes will change the recurrence interval of Phase 2 transport by no more than 0.1 year when compared to Current Conditions (2006). The frequency of flows equal to or exceeding that required to initiate Phase 2 transport is predicted to decrease at both Representative sites when compared to Current Conditions (2006). Given Current Conditions (2006) Phase 2 transport is calculated to occur approximately 26 days per year and 32 days per year at the upstream and downstream sites. For all Project alternatives with RFFAs, Phase 2 transport is predicted to occur a minimum of 18 days per year at the upstream site and 26 days per year at the downstream site. The maximum number of years between flows large enough to initiate Phase 2 sediment transport was calculated to be 2 years for both Current Conditions (2006) and all Project alternatives at both Representative sites.

Colorado River Basin

Flows required to initiate Phase 2 sediment transport were calculated for the Representative sites in the Colorado River for the Project alternatives with RFFAs based on the measured D_{16} material size observed at each of the sites. The relatively low frequency of the flows initiating Phase 2 transport calculated as part of this analysis shown below is believed to be heavily influenced by the use of the Parker and Wilcock and Crowe equations. As is indicated in Section 4.6.3.3.1, the Parker and Wilcock and Crowe equations result in unrealistically low estimates of sediment transport at some locations, including both sites on the Colorado River.

To account for the likely inaccuracies of the transport equations used for the Phase 2 analysis, the evaluation considered changes to the predicted frequency of the 1.5-year recurrent interval flood. The 1.5-year event is often uses as an approximation for bankfull flow and provides an estimate for flows when Phase 2 transport threshold is typically exceeded (Ryan 2002). The calculated flow along with the recurrence interval, flow frequency and maximum number of years between Phase 2 flows as well as for the 1.5-year flow based on Current Conditions (2006) hydrology were calculated and are presented on Table 4.6.3-14.

Table 4.6.3-14
Phase 2 Sediment Transport Calculations – Colorado River Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/ W-C)	Maximum Duration Between Phase 2 Flows (yrs) (Parker/ W-C)
CR1	22 (coarse gravel)	3,500 / 2,440	Current Conditions	12 / 5	0.3% / 0.8%	24 / 9
			Full Use	10 / 5	0.3% / 0.7%	24 / 11
			No Action	10 / 5	0.3% / 0.7%	24 / 11
			Proposed Action with RFFAs	9 / 6	0.3% / 0.6%	24 / 11
			Alt. 8a with RFFAs	9 / 6	0.3% / 0.6%	24 / 11

Table 4.6.3-14 (continued)
Phase 2 Sediment Transport Calculations – Colorado River Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/ W-C)	Maximum Duration Between Phase 2 Flows (yrs) (Parker/ W-C)
CR2	10 (medium gravel)	1,940 / 1,380	Current Conditions	3 / 3	1.9% / 3.9%	8 / 7
			Full Use	4 / 3	1.7% / 3.1%	9 / 7
			No Action	4 / 3	1.6% / 3.0%	9 / 7
			Proposed Action with RFFAs	4 / 3	1.4% / 2.4%	9 / 8
			Alt. 8a with RFFAs	4 / 3	1.4% / 2.4%	9 / 8
Site	**Alternative**	**$Q_{1.5}$ Flow (cfs)**	**% Change from Current Conditions $Q_{1.5}$ Flow**	**Recurrence Interval for $Q_{1.5}$ Current Conditions Flow (yrs)**	**Frequency $Q_{1.5}$ Current Conditions Flow is Equaled or Exceeded**	**Maximum Duration Between $Q_{1.5}$ Current Conditions Flow (yrs)**
CR1	Current Conditions	601	N/A	1.5	7.4%	3
	Full Use	396	-34%	1.9	5.2%	3
	No Action	384	-36%	2.0	5.1%	3
	Proposed Action with RFFAs	382	-36%	2.0	4.8%	3
	Alt. 8a with RFFAs	382	-36%	2.0	4.8%	3
CR2	Current Conditions	802	N/A	1.5	7.6%	3
	Full Use	868	+8%	1.4	6.0%	2
	No Action	894	+11%	1.4	5.9%	2
	Proposed Action with RFFAs	841	+5%	1.5	5.4%	2
	Alt. 8a with RFFAs	841	+5%	1.5	5.5%	2

Notes:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.
N/A = not applicable

Figures showing Phase 2 modeling results in the Colorado River are presented in Figures H-21.19 to H-21.22 in Appendix H-21. Flow frequency curves for the Colorado River are presented in Figures H-20.10 and H-20.11 in Appendix H-20.

Calculated flows required to initiate Phase 2 sediment transport were predicted to be higher above the confluence with the Williams Fork (CR1) than below (CR2) using the Parker and Wilcock and Crowe equations. This is the result of the larger D_{16} observed at CR1. Given the higher flows that are predicted to initiate Phase 2 transport upstream of the Williams Fork, the recurrence interval of Phase 2 transport is higher at the upstream site. At CR1 Phase 2 transport is predicted to occur at a recurrence interval of approximately 9 years for Current Conditions (2006) using the Parker and Wilcock and Crowe equations. No notable change in the recurrence interval of Phase 2 transport is predicted for any of the alternatives with RFFAs with all alternatives having average recurrence intervals in the 8-9 year range. Similar trends are observed for the frequency of flows equaling or exceeding Phase 2 transport and the maximum duration between Phase 2 flows based on the two equations. In all cases differences in timing and frequency between Current Conditions (2006) and the Project alternatives with RFFAs are minimal. For Current Conditions (2006) and all Project alternatives with RFFAs, Phase 2 transport is expected to occur for an average of approximately 2 days per year; the longest interval between events causing Phase 2 transport is predicted to be 17-18 years for all alternatives.

The magnitude of flow predicted to occur with a recurrence interval of 1.5-years is predicted to decrease for all alternatives with RFFAs when compared to Current Conditions (2006) at CR1 based on the flow frequency analysis. The Current Condition (2006) 1.5-year flow of 601 cfs is predicted to occur approximately every 1.9 to 2.0 years for the different Project alternatives with RFFAs. A flow of 601 cfs is predicted to occur approximately 27 days per year given Current Conditions (2006) verses roughly 19 days per year for the Full Use of the Existing System and the No Action Alternative and 18 days per year for the Proposed Action and Alternative 8a. The longest interval between a flow of 601 cfs was found to be three years for Current Conditions (2006) and all Project alternatives with RFFAs.

At CR2 Phase 2 transport is predicted to occur at a recurrence interval of approximately 3 years for Current Conditions (2006); for all Project alternatives with RFFAs Phase 2 transport is predicted to have a recurrence interval in the range of 3.3-3.6 years using the Parker and Wilcock and Crowe equations. For Current Conditions (2006) Phase 2 transport is expected to occur for an average of approximately 11 days per year. For the Full Use of the Existing System and No Action Alternative flows causing Phase 2 transport are predicted to occur an average of 9 days per year. The Proposed Action and Alternative 8a will have approximately 7 days per year where flows equal or exceed those required for Phase 2 transport based on the Parker and Wilcock and Crowe equations. The longest interval between Phase 2 transport events is predicted to be approximately 8 years for Current Conditions (2006); this value is predicted to range from approximately 8-9 years for the various Project alternatives with RFFAs.

The magnitude of flow predicted to occur with a recurrence interval of 1.5-years is predicted to increase for all alternatives with RFFAs when compared to Current Conditions (2006) at CR2 based on the flow frequency analysis. The Current Condition (2006) 1.5-year flow of 802 cfs is predicted to occur approximately every 1.4 to 1.5 years for the different Project alternatives with RFFAs. A flow of 802 cfs is predicted to occur approximately 28 days per year given Current Conditions (2006) verses roughly 22 days per year for the Full Use of the Existing System and the No Action Alternative and 20 days per year for the Proposed Action and Alternative 8a. The longest interval between a flow of 802 cfs was found to be three years for Current Conditions (2006) and two years for all Project alternatives with RFFAs.

Blue River Basin

Flows required to initiate Phase 2 sediment transport were calculated for the Representative site on the Blue River for the Project alternatives with RFFAs based on channel geometry and the measured D_{16} material size. Calculated flow along with the recurrence interval, flow frequency and maximum number of years between Phase 2 flows were calculated and are presented on Table 4.6.3-15. Figures showing Phase 2 modeling results in the Blue River are presented in Figures H-21.23 to H-21.24 in Appendix H-21.

Table 4.6.3-15
Phase 2 Sediment Transport Calculations – Blue River Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/ W-C)	Maximum Duration Between Phase 2 Flows (yrs) (Parker/ W-C)
BR1	30 (coarse gravel)	1,689 / 859	Current Conditions	1.6 / 1.3	2.5% / 7.8%	4 / 3
			Full Use	2 / 1.5	2.0% / 5.4%	7 / 3
			No Action	3 / 1.7	1.8% / 4.5%	7 / 6
			Proposed Action with RFFAs	2 / 1.6	1.9% / 4.9%	7 / 3
			Alt. 8a with RFFAs	2 / 1.6	1.9% / 5.0%	7 / 3

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At BR1 Phase 2 transport is predicted to occur at a recurrence interval of approximately 1.5 years for Current Conditions (2006). For Full Use of the Existing System, the Proposed Action and Alternative 8a with RFFAs the calculated average recurrence interval was found to be 1.8 years; a recurrence interval of approximately 2.4 years was predicted for the No Action Alternative. For Current Conditions (2006) Phase 2 transport is expected to occur for an average of approximately 19 days per year. For all Project alternatives with RFFAs Phase 2 transport flows are predicted to be equaled or exceeded an average of 11-14 days per year. The longest interval between Phase 2 transport events is predicted to be approximately 3.5 years for Current Conditions (2006); this value is predicted to range from approximately 5-7 years for the various Project alternatives with RFFAs.

North Fork South Platte River Basin

Flows required to initiate Phase 2 sediment transport were calculated for the Representative sites of the North Fork for the Project alternatives with RFFAs based on the measured D_{16} material size observed at each of the sites. The calculated flow along with the recurrence interval, flow frequency and maximum number of years between Phase 2 flows were calculated and are presented on Table 4.6.3-16. Figures showing Phase 2 modeling results in the North Fork South Platte River are presented in Figures H-21.25 to H-21.28 in Appendix H-21.

Table 4.6.3-16
Phase 2 Sediment Transport Calculations – North Fork South Platte River Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/ W-C)	Maximum Duration Between Phase 2 Flows (yrs) (Parker/ W-C)
NF1	24 (coarse gravel)	612 / 415	Current Conditions	3 / 1.1	0.2% / 5.1%	11 / 1
			Full Use	1.2 / 1	0.9% / 11.9%	6 / 0
			No Action	1.2 / 1	1.3% / 14.2%	3 / 0
			Proposed Action with RFFAs	1.2 / 1	2.1% / 16.4%	3 / 0
			Alt. 8a with RFFAs	1.2 / 1	1.9% / 16.2%	3 / 0
NF2	11 (medium gravel)	600 / 360	Current Conditions	1.9 / 1	1.5% / 13.5%	7 / 1
			Full Use	1.3 / 1	2.8% / 22.1%	4 / 0
			No Action	1.1 / 1	3.6% / 24.4%	1 / 0
			Proposed Action with RFFAs	1.1 / 1	5.6% / 26.5%	1 / 0
			Alt. 8a with RFFAs	1.1 / 1	5.5% / 26.4%	1 / 0

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Calculated flows required to initiate Phase 2 sediment transport were predicted to be similar at both the upstream site (NF1) and the downstream site (NF2). The larger D_{16} observed at NF1 likely contributes to Phase 2 flow being similar to that of the downstream location despite lower peak flows at this location. Given the additional water that will be transported through Roberts Tunnel for each alternative with RFFAs, the recurrence interval of Phase 2 transport is expected to decrease when compared to Current Conditions (2006). At NF1 Phase 2 transport is predicted to occur at a recurrence interval approximately 2.1 years for Current Conditions (2006). For each Project alternative with RFFAs the recurrence interval is predicted to decrease to approximately 1.1 years. At NF2 Phase 2 transport is predicted to occur at a recurrence interval of approximately 1.5 years for Current Conditions (2006); for all Project alternatives with RFFAs, Phase 2 transport is predicted to have a recurrence interval in the range of 1.1-1.2 years.

At NF1 Phase 2 transport is expected to occur for an average of approximately 10 days per year given Current Conditions (2006). For Full Use of the Existing System the average frequency is predicted to increase to approximately 23 days per year. The frequency increases to approximately 28 days per year for the No Action Alternative. For the Proposed Action and Alternative 8a, the frequency is predicted to increase to approximately 34 days per year. The longest interval between Phase 2 transport events is predicted to be approximately 6 years for Current Conditions (2006); this value is predicted to range from approximately 1.5-3 years for the various Project alternatives with RFFAs.

At NF2 Phase 2 transport is expected to occur for an average of approximately 27 days per year given Current Conditions (2006). For the Full Use of the Existing System the average frequency is predicted to increase to approximately 45 days per year. The frequency increases to approximately 51 days per year for the No Action Alternative. For the Proposed Action and Alternative 8a, the frequency is predicted to increase to approximately 59 days per year. The longest interval between Phase 2 transport events is predicted to be approximately 4 years for Current Conditions (2006); this value is predicted to range from approximately 0.5-2 years for the various Project alternatives with RFFAs.

South Boulder Creek Basin

Flows required to initiate Phase 2 sediment transport were calculated for the Representative sites in South Boulder Creek for the Project alternatives with RFFAs based on the measured D_{16} material size observed at each of the sites. The calculated flow along with the recurrence interval, flow frequency and maximum number of years between Phase 2 flows were calculated and are presented on Table 4.6.3-17. Figures showing Phase 2 modeling results in South Boulder Creek are presented in Figures H-21.29 to H-21.32 in Appendix H-21.

Using the Parker equation, the flow required to initiate Phase 2 transport was greater than the upper bound flow at SBC1 therefore the flow was undetermined. This is a result of the relatively large size of the D_{16} material. Flows, recurrence intervals and frequencies presented for SBC1 are therefore based solely on results from the Wilcock and Crowe equation.

Calculated flows required to initiate Phase 2 sediment transport were predicted to be greater at the upstream site (SBC1) than the lower site (SBC3). This is the result of the larger substrate size at SBC1. At SBC1 the recurrence interval for Phase 2 flows is estimated to be 4 years given Current Conditions (2006). The recurrence interval of flows required to initiate Phase 2 transport is not expected to change for Full Use of the Existing System or the No Action Alternative. Given the Proposed Action with RFFAs and Alternative 8a, the recurrence interval is predicted to decrease to 3 years.

Table 4.6.3-17
Phase 2 Sediment Transport Calculations – South Boulder Creek Basin

Site	D_{16} (mm) (size class)	$Q_{Phase\ 2}$ (cfs) (Parker/ W-C)	Alternative	Recurrence Interval (yrs) (Parker/ W-C)	Frequency Phase 2 Flow is Equaled or Exceeded (Parker/W-C)	Maximum Duration Between Phase 2 Flows (yrs) (Parker/ W-C)
SBC1	48 (very coarse gravel)	N/A / 973	Current Conditions	N/A / 4	N/A / 0.26%	N/A / 17
			Full Use	N/A / 4	N/A / 0.26%	N/A / 17
			No Action	N/A / 4	N/A / 0.30%	N/A / 14
			Proposed Action with RFFAs	N/A / 3	N/A / 0.38%	N/A / 7
			Alt. 8a with RFFAs	N/A / 3	N/A / 0.38%	N/A / 7
SBC3	22 (coarse gravel)	385 / 385	Current Conditions	1 / 1	12.8% / 12.8%	0 / 0
			Full Use	1 / 1	14.5% / 14.5%	0 / 0
			No Action	1 / 1	15.2% / 15.2%	0 / 0
			Proposed Action with RFFAs	1 / 1	8.7% / 8.7%	1 / 1
			Alt. 8a with RFFAs	1 / 1	8.7% / 8.7%	1 / 1

Notes:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.
N/A = not applicable

At SBC1 Phase 2 transport is expected to occur for an average of approximately 1 day per year given Current Conditions (2006) and all Project alternatives with RFFAs. The longest interval between Phase 2 transport events is predicted to be approximately 17 years for Current Conditions (2006) and Full Use of the Existing System. This maximum interval is predicted to decrease to 14 years for the No Action Alternative and 7 years for the Proposed Action and Alternative 8a.

At SBC3 flows required to initiate Phase 2 transport are expected to occur with a recurrence interval of 1 year given Current Conditions (2006); the recurrence interval is predicted to be unchanged by any of the Project alternatives with RFFAs. For Current Conditions (2006), flow initiating Phase 2 transport is predicted to be equaled or exceeded approximately 47 days per year. For Full Use of the Existing System the average frequency is predicted to increase to approximately 53 days per year. The frequency increases to approximately 55 days per year for the No Action Alternative. For the Proposed Action and Alternative 8a, the frequency is predicted to decrease to approximately 32 days per year. This decrease is a result of flow reductions during peak flow periods. For Current Conditions (2006), Full

Use of the Existing System, and the No Action Alternative flows necessary for Phase 2 transport are predicted to occur every year. Given the Proposed Action and Alternative 8a, the longest interval between Phase 2 transport events is predicted to be approximately 1 year.

Overall Phase 2 Transport Trends

Calculated Phase 2 sediment transport follows anticipated trends. The frequency of Phase 2 flows is predicted to decrease in areas where flow reductions are greatest and increased the most in areas with the largest increase in flows. Typically changes in Phase 2 sediment transport supply are greatest given the Proposed Action and Alternative 8a with RFFAs and least for Full Use of the Existing System.

4.6.3.8.1 5- and 10-Year Flood Events

Based on findings from Ryan including work in the Fraser River Basin (Ryan 1997), observed changes to channel morphology downstream of diversions were generally limited to unconstrained, wide pool-riffle sections with cobble bars; changes were typically not observed in other stream reaches. The absence of observed changes in channel morphology was attributed to the preservation of high magnitude, low frequency flood events such as the 5- and 10-year event (Ryan 1997). The magnitude of the 5- and 10-year peak flood event for the different Project alternatives with RFFAs was quantified and the recurrence interval of these flows were defined based on hydrology given Current Conditions (2006) to evaluate changes caused by the different Project alternatives with RFFAs. Results of this analysis are presented below. Flood frequency curves for each Representative site are provided in Appendix H-20.

Fraser River Basin

Five- and 10-year flood events were calculated for the Representative sites in the Fraser River Basin. The calculated flows for the Project alternatives with RFFAs are presented on Table 4.6.3-18. Presented results include the recurrence interval for each Project alternative with RFFAs based on Current Conditions (2006) hydrology. Results of the flood frequency analysis for sites in the Fraser River Basin are presented in Figures H-20.1 to H-20.7 in Appendix H-20.

Results indicate that the seven Representative sites can be considered as three different groups when describing anticipated changes in 5- and 10-year peak flows. One group includes sites FR3, FR4, and FR7. These sites include sites on St. Louis Creek (FR3) and Ranch Creek (FR4) downstream of Denver Water's diversions and one site on Vasquez Creek upstream Denver Water's diversion (FR7). At all of these locations only minor changes are expected for the 5- and 10-year flood events when compared to Current Conditions (2006). For all Project alternatives with RFFAs, flow changes are expected to cause the 5- and 10-year flood events to change by less than 5% when compared to Current Conditions (2006). Slight peak flow decreases are predicted at FR3, no changes are predicted at FR4 while slight increases are predicted at FR7. For all alternatives the recurrence interval of the 5- year event with adjusted hydrology is between 4 and 6 years based on Current Conditions (2006) hydrology. The adjusted 10-year peak flows have a recurrence interval of between 7 and 10 years based on Current Conditions (2006) hydrology.

Table 4.6.3-18
Five- and 10-Year Peak Flow Calculations – Fraser River Basin

Site	Alternative	Q_5 (cfs)	Q_{10} (cfs)	Recurrence Interval of Current Conditions Q_5 (yrs)	Recurrence Interval of Current Conditions Q_{10} (yrs)
FR1	Current Conditions	262	359	5	10
	Full Use	249	362	6	9
	No Action	235	330	6	12
	Proposed Action with RFFAs	212	274	9	18
	Alt. 8a with RFFAs	214	275	9	17
FR2	Current Conditions	1,264	1,639	5	10
	Full Use	1,211	1,652	5	10
	No Action	1,179	1,649	6	10
	Proposed Action with RFFAs	1,167	1,454	8	12
	Alt. 8a with RFFAs	1,167	1,455	8	12
FR3	Current Conditions	299	335	5	10
	Full Use	299	335	5	10
	No Action	296	335	6	10
	Proposed Actions with RFFAs	278	335	6	10
	Alt. 8a with RFFAs	278	335	6	10
FR4	Current Conditions	101	126	5	10
	Full Use	101	126	5	10
	No Action	101	126	5	10
	Proposed Action with RFFAs	101	126	5	10
	Alt. 8a with RFFAs	101	126	5	10

Table 4.6.3-18 (continued)
Five- and 10-Year Peak Flow Calculations – Fraser River Basin

Site	Alternative	Q_5 (cfs)	Q_{10} (cfs)	Recurrence Interval of Current Conditions Q_5 (yrs)	Recurrence Interval of Current Conditions Q_{10} (yrs)
FR5	Current Conditions	168	229	5	10
	Full Use	168	229	5	10
	No Action	159	229	6	10
	Proposed Action with RFFAs	149	175	8	18
	Alt. 8a with RFFAs	149	175	8	18
FR6	Current Conditions	70	83	5	10
	Full Use	66	98	6	8
	No Action	63	88	7	9
	Proposed Action with RFFAs	57	75	9	14
	Alt. 8a with RFFAs	58	75	9	14
FR7	Current Conditions	305	333	5	10
	Full Use	306	333	5	10
	No Action	310	340	4	8
	Proposed Action with RFFAs	319	348	4	7
	Alt. 8a with RFFAs	319	340	4	8

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At FR2, the downstream site on the main stem of the Fraser River changes predicted may alter the peak 5- and 10-year flows by up to approximately 10% when compared to Current Conditions (2006). Predicted changes are greatest for the Proposed Action and Alternative 8a with RFFAs. For all alternatives with RFFAs the recurrence interval of the 5-year event with adjusted hydrology is between 5 and 8 years based on Current Conditions (2006) hydrology. The adjusted 10-year peak flows have a recurrence interval of between 10 and 12 years based on Current Conditions (2006) hydrology.

The greatest changes in peak 5- and 10-year flood flows is predicted at FR1, FR5, and FR6, the three Representative sites below Denver's highest priority diversions. In general changes are least dramatic for Full Use of the Existing System with the Proposed Action and Alternative 8a with RFFAs having the greatest changes when compared to Current Conditions (2006). Changes resulting from the No Action Alternative are between the other two groups.

At FR1, FR5, and FR6, for all alternatives with RFFAs, the recurrence interval of the 5-year event with adjusted hydrology is between 5 and 9 years based on Current Conditions (2006) hydrology. The adjusted 10-year peak flows have a recurrence interval of between 8 and 18 years based on Current Conditions (2006) hydrology.

Williams Fork River Basin

Five- and 10-year flood events were calculated for the Representative sites in the Williams Fork River Basin. The calculated flows for the Project alternatives with RFFAs are presented on Table 4.6.3-19. Presented results include the recurrence interval for each Project alternative with RFFAs based on Current Conditions (2006) hydrology. Results of the flood frequency analysis for sites in the Williams Fork River Basin are presented in Figures H-20.8 and H-20.9 in Appendix H-20.

Table 4.6.3-19
Five- and 10-Year Peak Flow Calculations – Williams Fork River Basin

Site	Alternative	Q_5 (cfs)	Q_{10} (cfs)	Recurrence Interval of Current Conditions Q_5 (yrs)	Recurrence Interval of Current Conditions Q_{10} (yrs)
WF1	Current Conditions	414	463	5	10
	Full Use	414	463	5	10
	No Action	414	463	5	10
	Proposed Action with RFFAs	414	463	5	10
	Alt. 8a with RFFAs	414	463	5	10
WF2	Current Conditions	276	292	5	10
	Full Use	276	292	5	10
	No Action	276	292	5	10
	Proposed Action with RFFAs	276	292	5	10
	Alt. 8a with RFFAs	276	292	5	10

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Results show that no changes to the peak 5- and 10-year flood events are predicted at either WF1 or WF2 for any of the Project alternatives with RFFAs. Given the lower priority of diversions in the Williams Fork River Basin, no additional water is predicted to be taken at these locations during peak flow periods.

Colorado River Basin

Five- and 10-year flood events were calculated for the Representative sites in the Colorado River. The calculated flows for the Project alternatives with RFFAs are presented on Table 4.6.3-20. Presented results include the recurrence interval for each Project alternative with RFFAs based on Current Conditions (2006) hydrology. Results of the flood frequency analysis for sites in the Colorado River are presented in Figures H-20.10 and H-20.11 in Appendix H-20.

Table 4.6.3-20
Five- and 10-Year Peak Flow Calculations – Colorado River Basin

Site	Alternative	Q_5 (cfs)	Q_{10} (cfs)	Recurrence Interval of Current Conditions Q_5 (yrs)	Recurrence Interval of Current Conditions Q_{10} (yrs)
CR1	Current Conditions	2,696	3,406	5	10
	Full Use	2,362	3,589	6	9
	No Action	2,254	3,581	6	9
	Proposed Action with RFFAs	2,235	3,629	8	9
	Alt. 8a with RFFAs	2,235	3,630	8	9
CR2	Current Conditions	2,877	3,760	5	10
	Full Use	2,572	4,062	5	7
	No Action	2,552	4,053	6	7
	Proposed Action with RFFAs	2,546	4,097	6	8
	Alt. 8a with RFFAs	2,547	4,098	6	8

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Results show that at both CR1 and CR2 the peak 5-year flood is predicted to decrease while the peak 10-year flood is predicted to increase for all Project alternatives with RFFAs when compared to Current Conditions (2006). For the 5-year event, peak flows are reduced by the smallest amount for Full Use of the Existing System while reductions for the No Action Alternative, the Proposed Action and Alternative 8a are similar. Predicted flow increases are generally similar for all Project alternatives with RFFAs when compared to Current Conditions (2006). For all alternatives the recurrence interval of the 5- year event with adjusted hydrology is between 5 and 8 years based on Current Conditions (2006) hydrology. The adjusted 10-year peak flows have a recurrence interval of between 7 and 9 years based on Current Conditions (2006) hydrology.

Blue River Basin

Five- and 10-year flood events were calculated for the Representative sites in the Blue River. The calculated flows for the Project alternatives with RFFAs are presented on Table 4.6.3-21. Presented results include the recurrence interval for each Project alternative with RFFAs based on Current Conditions (2006) hydrology. Results of the flood frequency analysis for the site on the Blue River are presented in Figure H-20.12 in Appendix H-20.

Table 4.6.3-21
Five- and 10-Year Peak Flow Calculations – Blue River Basin

Site	Alternative	Q_5 (cfs)	Q_{10} (cfs)	Recurrence Interval of Current Conditions Q_5 (yrs)	Recurrence Interval of Current Conditions Q_{10} (yrs)
BR1	Current Conditions	2,335	2,430	5	10
	Full Use	2,272	2,380	8	12
	No Action	2,242	2,304	13	19
	Proposed Action with RFFAs	2,282	2,402	7	12
	Alt. 8a with RFFAs	2,287	2,402	7	12

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Results indicate that changes to the peak 5- and 10-year flood events are similar for Full Use of the Existing System, the Proposed Action, and Alternative 8a. In each of these alternatives the recurrence interval of the 5-year event with adjusted hydrology is between 7 and 8 years based on Current Conditions (2006) hydrology. The adjusted 10-year peak flows have a recurrence interval of 12 years based on Current Conditions (2006) hydrology. The greatest change from Current Conditions (2006) is predicted for the No Action Alternative. Given this alternative’s hydrology, the adjusted 5-year flow has a recurrence interval of 13 years using Current Conditions (2006) hydrology. The 10-year peak flood with adjusted hydrology has a recurrence interval of 19 years with Current Conditions (2006) hydrology. It should be noted that while the recurrence intervals show relatively large changes for the No Action Alternative, the actual change in the 5- and 10-year flows for this alternative are only approximately 5% less than the same flows given Current Conditions (2006).

North Fork South Platte River Basin

Five- and 10-year flood events were calculated for the Representative sites in the North Fork. The calculated flows for the Project alternatives with RFFAs are presented on Table 4.6.3-22. Presented results include the recurrence interval for each Project alternative with RFFAs based on Current Conditions (2006) hydrology. Results of the flood frequency analysis for sites in the North Fork South Platte River are presented in Figures H-20.13 and H-20.14 in Appendix H-20.

Table 4.6.3-22
Five- and 10-Year Peak Flow Calculations – North Fork South Platte River Basin

Site	Alternative	Q_5 (cfs)	Q_{10} (cfs)	Recurrence Interval of Current Conditions Q_5 (yrs)	Recurrence Interval of Current Conditions Q_{10} (yrs)
NF1	Current Conditions	638	645	5	10
	Full Use	654	667	3	4
	No Action	656	666	2	3
	Proposed Action with RFFAs	656	668	2	3
	Alt. 8a with RFFAs	656	668	2	3
NF2	Current Conditions	762	838	5	10
	Full Use	763	838	5	10
	No Action	763	838	5	10
	Proposed Action with RFFAs	772	838	5	10
	Alt. 8a with RFFAs	773	838	5	10

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Changes in the 5- and 10-year flood event are predicted at NF1. For all Project alternatives with RFFAs, the peak 5-year flood is predicted to increase by between 16 and 18 cfs, which represent increases of less than 3% when compared to Current Conditions (2006). Despite the small changes, for all alternatives the recurrence interval of the 5-year event with adjusted hydrology is between 2 and 3 years based on Current Conditions (2006) hydrology. For all Project alternatives with RFFAs, the peak 10-year flood is predicted to increase by between 21 and 23 cfs, which represent increases of less than 4% when compared to Current Conditions (2006). Despite the small changes, for all alternatives the recurrence interval of the 10-year event with adjusted hydrology is between 3 and 4 years based on Current Conditions (2006) hydrology. The large changes in recurrence intervals despite the small changes in absolute flows is a function of the peak flows at this location already being highly regulated and peak flows for different frequency events having similar magnitudes.

Results show that slight increases in the 5-year event for the different Project alternatives with RFFAs are predicted at NF2 when compared to Current Conditions (2006); however, the recurrence interval of the 5-year event using adjusted hydrology remains at 5-years based on Current Conditions (2006). No changes in the 10-year flood are predicted for any of the alternatives.

South Boulder Creek Basin

Five- and 10-year flood events were calculated for the Representative sites in South Boulder Creek. The calculated flows for the Project alternatives with RFFAs are presented on Table 4.6.3-23. Presented results include the recurrence interval for each Project alternative with RFFAs based on Current Conditions (2006) hydrology. Results of the flood frequency analysis for sites in South Boulder Creek are presented in Figures H-20.15 and H-20.16 in Appendix H-20.

Table 4.6.3-23
Five- and 10-Year Peak Flow Calculations – South Boulder Creek Basin

Site	Alternative	Q_5 (cfs)	Q_{10} (cfs)	Recurrence Interval of Current Conditions Q_5 (yrs)	Recurrence Interval of Current Conditions Q_{10} (yrs)
SBC1	Current Conditions	984	1,003	5	10
	Full Use	985	1,003	5	10
	No Action	988	1,003	4	10
	Proposed Action with RFFAs	993	1,015	4	7
	Alt. 8a with RFFAs	993	1,015	4	7
SBC3	Current Conditions	741	821	5	10
	Full Use	766	834	4	8
	No Action	750	815	4	10
	Proposed Action with RFFAs	687	737	12	>45
	Alt. 8a with RFFAs	690	735	12	>45

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

Results show very slight increases in the magnitude of the 5- and 10-year event for the different Project alternatives with RFFAs are predicted at SBC1 when compared to Current Conditions (2006). The recurrence interval of Current Conditions (2006) 5- and 10-year flows based on adjusted hydrology for the different alternatives either remains the same or decreases slightly for all alternatives.

Changes in the 5- and 10-year flood event are predicted at SBC3 for the Proposed Action and Alternative 8a while little changes are predicted for Full Use of the Existing System or the No Action Alternative. For the Proposed Action and Alternative 8a, the 5-year event based on current hydrology will have a recurrence interval of 12 years; the 10-year flow from current hydrology is predicted to have a recurrence interval in excess of 45 years. The high recurrence interval predicted for the Proposed Action and Alternative 8a is based on planned operations of Gross Reservoir where less flow would be released during traditional peak flow periods.

Overall Peak 5- and 10-Year Flow Trends

The recurrence interval of 5- and 10-year flood flows based on Current Condition (2006) hydrology is expected to change for some alternatives with RFFAs, although changes are not consistent. In general the recurrence interval of these flows will increase within the Fraser River Basin and Blue River where diversions are predicted to increase. No changes are predicted in the Williams Fork River while the recurrence interval are expected to both increase and decrease in the Colorado River. In general the recurrence interval of Current Conditions (2006) 5- and 10-year flood flows are expected to decrease in the North Fork South Platte River and South Boulder Creek, although they remained unchanged or decrease in some conditions.

4.6.3.9 Effective Discharge

Effective discharge was calculated at each of the Reference Reaches for all alternatives with RFFAs. The magnitude and recurrence interval of the effective discharge was quantified and compared to Current Conditions (2006) to evaluate changes caused by the different Project alternatives with RFFAs. Effective discharge values presented below are the average of the effective discharge values calculated using the four different transport equations. Results of the calculations are presented in Appendix H-9.

There are different methods that can be used to calculate effective discharge, each with a level of uncertainty. One of the differences in calculation methods is the way that flows are grouped together or “binned.” Bins refer to the way flow data are combined for estimating sediment transport over a specific range of flows. Many times, flows are binned by separating flows into equal or arithmetic bins. Another method is to bin the flow data into logrithmetically spaced bins.

Both of these methods of flow binning were evaluated as part of the effective discharge calculations. Results showed that binning flow data logrithmetically generally produced a smooth curve with a single peak for effective discharge that was in the anticipated flow range. Results obtained when binning the data arithmetically were found to produce more erratic results rather than a smooth curve, often with multiple peaks and an effective discharge outside of normal ranges. Upon inspection, the results from the arithmetic binning were found to be heavily influenced by specific flow rates, which resulted in the multiple peaks. For this reason, logrithmetic binning was selected as the more appropriate method for estimating effective discharge.

Fraser River Basin

The effective discharge was calculated for the Representative sites in the Fraser River Basin. The calculated flow and recurrence interval for each of the Project alternatives with RFFAs are presented on Table 4.6.3-24. Presented results include the recurrence interval for each Project alternative with RFFAs, the magnitude of effective discharge compared to Current Conditions (2006) and differences in the anticipated recurrence interval of effective discharge as compared to Current Conditions (2006) hydrology. Effective discharge curves for sites in the Fraser River Basin are presented in Figures H-9.17 to H-9.51 in Appendix H-9.

Table 4.6.3-24
Effective Discharge – Fraser River Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
FR1	Current Conditions	249	4	100%	0
	Full Use	244	5	98%	1
	No Action	284	7	114%	3
	Proposed Action with RFFAs	284	12	114%	8
	Alt. 8a with RFFAs	284	12	114%	8
FR2	Current Conditions	1,168	4	100%	0
	Full Use	1,302	6	111%	2
	No Action	1,041	3	89%	-1
	Proposed Action with RFFAs	1,080	4	92%	0
	Alt. 8a with RFFAs	1,348	9	115%	5
FR3	Current Conditions	259	3	100%	0
	Full Use	259	3	100%	0
	No Action	259	3	100%	0
	Proposed Action with RFFAs	259	4	100%	1
	Alt. 8a with RFFAs	259	4	100%	1

Table 4.6.3-24 (continued)
Effective Discharge – Fraser River Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
FR4	Current Conditions	85	3	100%	0
	Full Use	90	3	106%	0
	No Action	102	5	120%	2
	Proposed Action with RFFAs	102	5	120%	2
	Alt. 8a with RFFAs	90	3	106%	0
FR5	Current Conditions	169	5	100%	0
	Full Use	183	7	108%	2
	No Action	191	7	113%	2
	Proposed Action with RFFAs	183	12	108%	7
	Alt. 8a with RFFAs	191	13	113%	8
FR6	Current Conditions	88	11	100%	0
	Full Use	87	8	99%	-3
	No Action	83	9	94%	-2
	Proposed Action with RFFAs	91	14	103%	3
	Alt. 8a with RFFAs	91	14	103%	3
FR7	Current Conditions	187	1.2	100%	0
	Full Use	187	1.2	100%	0
	No Action	262	2	140%	0.8
	Proposed Action with RFFAs	262	1.5	140%	0.3
	Alt. 8a with RFFAs	191	1.1	102%	-0.1

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At FR1, the effective discharge was calculated to be 249 cfs with a recurrence interval of 4 years for Current Conditions (2006). Little change is predicted in the effective discharge for Full Use of the Existing System as the calculated flow decreases by only 4 cfs. For the No Action Alternative, the Proposed Action, and Alternative 8a the effective discharge is predicted to increase to 284 cfs. Given the increased flow and predicted changes in the annual hydrograph, the recurrence interval of effective discharge is predicted to increase to 7 years for the No Action Alternative and 12 years for the Proposed Action and Alternative 8a.

At FR2, the effective discharge was calculated to be 1,168 cfs with a recurrence interval of 4 years for Current Conditions (2006). The magnitude of effective discharge and its recurrence interval is different for the various Project alternatives with RFFAs. Decreases in the effective discharge flow are predicted for the No Action Alternative and the Proposed Action with RFFAs. For these alternatives the recurrence interval is predicted to range from 3-4 years. Flow and recurrence interval increases are predicted for the effective discharge for Full Use of the Existing System (6-year recurrence interval) and Alternative 8a (9-year recurrence interval).

The effective discharge for Current Conditions (2006) and all Project alternatives with RFFAs are predicted to be 259 cfs at FR3. For Current Conditions (2006), Full Use of the Existing System and the No Action Alternative the recurrence interval of this flow is 3 years. This same flow is predicted to have a recurrence interval of 4 years for the Proposed Action and Alternative 8a.

At FR4, the effective discharge was calculated to be 85 cfs with a recurrence interval of 3 years for Current Conditions (2006). For Full Use of the Existing System and Alternative 8a, the effective discharge is predicted to increase to 90 cfs; the recurrence interval of this flow is unchanged when compared to Current Conditions (2006). Effective discharge is predicted to be 102 cfs for the No Action Alternative and the Proposed Action with RFFAs, which corresponds to a recurrence interval of 4 years.

At FR5, the effective discharge was calculated to be 169 cfs with a recurrence interval of 5 years for Current Conditions (2006). For Full Use of the Existing System and the Proposed Action with RFFAs, the effective discharge is predicted to increase to 183 cfs; the recurrence interval of this flow is 7 years for Full Use of the Existing System and 12 years for the Proposed Action with RFFAs. Effective discharge is predicted to be 191 cfs for the No Action Alternative (7-year recurrence interval) and Alternative 8a (13-year recurrence interval).

At FR6, the effective discharge was calculated to be 88 cfs with a recurrence interval of 11 years for Current Conditions (2006). A slight decrease in effective discharge magnitude is expected under Full Use of the Existing System (87 cfs) and the No Action Alternative (83 cfs). Slight increases in the effective discharge magnitude are predicted for the Proposed Action and Alternative 8a with a calculated flow of 91 cfs for both alternatives. Recurrence intervals for effective discharge are predicted to range from a low of 8 years for Full Use of the Existing System to 14 years of the Proposed Action and Alternative 8a. The predicted recurrence interval for the No Action Alternative is 9 years.

At FR7, the effective discharge was calculated to be 187 cfs with a recurrence interval of 1.2 years for Current Conditions (2006). This discharge is generally unchanged for Full

Use of the Existing System and Alternative 8a where effective discharge ranges from 187 cfs to 191 cfs. Recurrence intervals for these two alternatives range between 1.1 and 1.2 years. Effective discharge is predicted to increase to 262 cfs for the No Action Alternative (2 year recurrence interval) and the Proposed Action with RFFAs (1.5-year recurrence interval).

Williams Fork River Basin

The effective discharge was calculated for the Representative sites in the Williams Fork River Basin. The calculated flow and recurrence interval for each of the Project alternatives with RFFAs are presented on Table 4.6.3-25. Presented results include the recurrence interval for each Project alternative with RFFAs, the magnitude of effective discharge compared to Current Conditions (2006) and differences in the anticipated recurrence interval of effective discharge as compared to Current Conditions (2006) hydrology. Effective discharge curves for sites in the Williams Fork River Basin are presented in Figures H-9.52 to H-9.61 in Appendix H-9.

Table 4.6.3-25
Effective Discharge – Williams Fork River Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
WF1	Current Conditions	281	1.6	100%	0
	Full Use	281	1.6	100%	0
	No Action	323	1.9	115%	0.3
	Proposed Action with RFFAs	323	2.0	115%	0.4
	Alt. 8a with RFFAs	281	1.8	100%	0.2
WF2	Current Conditions	182	1.4	100%	0
	Full Use	182	1.4	100%	0
	No Action	233	3	128%	1.6
	Proposed Action with RFFAs	217	2	119%	0.6
	Alt. 8a with RFFAs	182	1.6	100%	0.2

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At WR1, the effective discharge was calculated to be 281 cfs with a recurrence interval of 1.6 years for Current Conditions (2006). No change is predicted in the magnitude of effective discharge for Full Use of the Existing System or Alternative 8a. The recurrence interval of effective discharge is predicted to remain at 1.6 years for Full Use of the Existing System and increase to 1.8 years for Alternative 8a. For the No Action Alternative and the Proposed Action with RFFAs the effective discharge is predicted to increase to 323 cfs. Given the increased flow and predicted changes in the annual hydrograph, the recurrence interval of effective discharge is predicted to increase to between 1.9 and 2 years for these Project alternatives with RFFAs.

At WR2, the effective discharge was calculated to be 182 cfs with a recurrence interval of 1.4 years for Current Conditions (2006). No change is predicted in the magnitude of effective discharge for Full Use of the Existing System or Alternative 8a. The recurrence interval of effective discharge is predicted to remain at 1.4 years for Full Use of the Existing System and increase to 1.6 years for Alternative 8a. For the No Action Alternative and the Proposed Action with RFFAs, the effective discharge is predicted to increase to 233 cfs and 217 cfs, respectively. Given the increased flow and predicted changes in the annual hydrograph, the recurrence interval of effective discharge is predicted to increase to between 2 and 3 years for these Project alternatives with RFFAs.

Colorado River Basin

The effective discharge was calculated for the Representative sites in the Colorado River. The calculated flow and recurrence interval for each of the Project alternatives with RFFAs are presented on Table 4.6.3-26. Presented results include the recurrence interval for each Project alternative with RFFAs, the magnitude of effective discharge compared to Current Conditions (2006) and differences in the anticipated recurrence interval of effective discharge as compared to Current Conditions (2006) hydrology. Effective discharge curves for sites in the Fraser River Basin are presented in Figures H-9.62 to H-9.71 in Appendix H-9.

Table 4.6.3-26
Effective Discharge – Colorado River Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
CR1	Current Conditions	3,178	7	100%	0
	Full Use	3,205	8	101%	1
	No Action	3,202	9	101%	2
	Proposed Action with RFFAs	3,342	9	105%	2
	Alt. 8a with RFFAs	2,926	8	92%	1

Table 4.6.3-26 (continued)
Effective Discharge – Colorado River Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
CR2	Current Conditions	3,620	9	100%	0
	Full Use	3,628	7	100%	-2
	No Action	3,813	8	105%	-1
	Proposed Action with RFFAs	3,813	8	105%	-1
	Alt. 8a with RFFAs	3,734	8	103%	-1

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At CR1, the effective discharge was calculated to be 3,182 cfs with a recurrence interval of 7 years for Current Conditions (2006). Changes to the magnitude of effective discharges are predicted to be within 8% of Current Conditions (2006) for all Project alternatives with RFFAs. The recurrence interval of effective discharge is predicted to be 8 years for Full Use of the Existing System and Alternative 8a. A recurrence interval of 9 years is predicted for effective discharge given the No Action Alternative and the Proposed Action with RFFAs.

At CR2, the effective discharge was calculated to be 3,620 cfs with a recurrence interval of 9 years for Current Conditions (2006). Changes to the magnitude of effective discharges are predicted to be within 5% of Current Conditions (2006) for all Project alternatives with RFFAs. The recurrence interval of effective discharge is predicted to be 7 years for Full Use of the Existing System and 8 years for the No Action Alternative, the Proposed Action, and Alternative 8a.

Blue River Basin

The effective discharge was calculated for the Representative sites in the Blue River. The calculated flow and recurrence interval for each of the Project alternatives with RFFAs are presented on Table 4.6.3-27. Presented results include the recurrence interval for each Project alternative with RFFAs, the magnitude of effective discharge compared to Current Conditions (2006) and differences in the anticipated recurrence interval of effective discharge as compared to Current Conditions (2006) hydrology. Effective discharge curves for the site in the Blue River are presented in Figures H-9.72 to H-9.76 in Appendix H-9.

Table 4.6.3-27
Effective Discharge – Blue River Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
BR1	Current Conditions	2,052	3	100%	0
	Full Use	2,260	5	110%	2
	No Action	2,298	9	112%	6
	Proposed Action with RFFAs	2,298	6	112%	3
	Alt. 8a with RFFAs	2,298	5	112%	2

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At BR1, the effective discharge was calculated to be 2,052 cfs with a recurrence interval of 3 years for Current Conditions (2006). Changes to the magnitude of effective discharges are predicted to increase by between 10% and 12% when compared to Current Conditions (2006) for all Project alternatives with RFFAs. The recurrence interval of effective discharge is predicted to be 5 years for Full Use of the Existing System and Alternative 8a. A recurrence interval of 9 years is predicted for effective discharge given the No Action Alternative and a recurrence interval of 6 years is predicted for the effective discharge given the Proposed Action with RFFAs.

North Fork South Platte River Basin

The effective discharge was calculated for the Representative sites in the North Fork. The calculated flow and recurrence interval for each of the Project alternatives with RFFAs are presented on Table 4.6.3-28. Presented results include the recurrence interval for each Project alternative with RFFAs, the magnitude of effective discharge compared to Current Conditions (2006) and differences in the anticipated recurrence interval of effective discharge as compared to Current Conditions (2006) hydrology. Effective discharge curves for sites in the North Fork South Platte River are presented in Figures H-9.77 to H-9.86 in Appendix H-9.

At NF1, the effective discharge was calculated to be 465 cfs with a recurrence interval of 1.4 years for Current Conditions (2006). The magnitude of effective discharge is predicted to increase to 515 cfs with a recurrence interval of 1.1 years for Full Use of the Existing System. The magnitude of effective discharge is predicted to increase to 592 cfs, which has a recurrence interval of 1.2 years for the No Action Alternative, the Proposed Action, and Alternative 8a.

Table 4.6.3-28
Effective Discharge – North Fork South Platte River Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
NF1	Current Conditions	465	1.4	100%	0
	Full Use	515	1.1	111%	-0.3
	No Action	592	1.2	127%	-0.2
	Proposed Action with RFFAs	592	1.2	127%	-0.2
	Alt. 8a with RFFAs	592	1.2	127%	-0.2
NF2	Current Conditions	549	1.5	100%	0
	Full Use	544	1.1	99%	-0.4
	No Action	602	1.1	110%	-0.4
	Proposed Action with RFFAs	602	1.1	110%	-0.4
	Alt. 8a with RFFAs	602	1.1	110%	-0.4

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At NF2, the effective discharge was calculated to be 549 cfs with a recurrence interval of 1.5 years for Current Conditions (2006). The magnitude of effective discharge is predicted to remain relatively consistent (544 cfs) for Full Use of the Existing System, while the recurrence interval decreases to 1.1 years. The magnitude of effective discharge is predicted to increase to 602 cfs, which has a recurrence interval of 1.1 years for the No Action Alternative, the Proposed Action, and Alternative 8a.

South Boulder Creek Basin

The effective discharge was calculated for the Representative sites in South Boulder Creek. The calculated flow and recurrence interval for each of the Project alternatives with RFFAs are presented on Table 4.6.3-29. Presented results include the recurrence interval for each Project alternative with RFFAs, the magnitude of effective discharge compared to Current Conditions (2006) and differences in the anticipated recurrence interval of effective discharge as compared to Current Conditions (2006) hydrology. Effective discharge curves for sites in South Boulder Creek are presented in Figures H-9.87 to H-9.96 in Appendix H-9.

Table 4.6.3-29
Effective Discharge – South Boulder Creek Basin

Site	Alternative	$Q_{effective}$ (cfs)	Recurrence Interval of $Q_{effective}$ (yrs)	$Q_{effective}$ as % of Current Conditions (%)	RI Change from Current Conditions (yrs)
SBC1	Current Conditions	742	1.5	100%	0
	Full Use	730	1.5	98%	0
	No Action	942	3	127%	1.5
	Proposed Action with RFFAs	942	2	127%	0.5
	Alt. 8a with RFFAs	843	1.4	114%	-0.1
SBC3	Current Conditions	520	1	100%	0
	Full Use	536	1	103%	0
	No Action	512	1.1	98%	0.1
	Proposed Action with RFFAs	512	1.4	98%	0.1
	Alt. 8a with RFFAs	563	1.8	108%	0.1

Note:
Hydrologic changes would be similar for the Proposed Action and Alternative 1c, and for Alternatives 8a, 10a, and 13a. Therefore, the evaluation of impacts on channel morphology is presented for Full Use of the Existing System, the No Action Alternative, the Proposed Action, and Alternative 8a.

At SBC1, the effective discharge was calculated to be 742 cfs with a recurrence interval of 1.5 years for Current Conditions (2006). The magnitude of effective discharge is predicted to decrease slightly to 730 cfs with the recurrence interval remaining at 1.5 years for Full Use of the Existing System. The magnitude of effective discharge is predicted to increase to 942 cfs for the No Action Alternative (3-year recurrence interval) and the Proposed Action with RFFAs (2-year recurrence interval). The magnitude of effective discharge is predicted to be 843 cfs, which has a recurrence interval of 1.4 years for Alternative 8a.

At SBC3, the effective discharge was calculated to be 520 cfs with a recurrence interval of 1 year for Current Conditions (2006). The magnitude of effective discharge is predicted to remain within 8% of Current Conditions (2006) with the recurrence interval of effective discharge predicted to range from 1 to 1.8 years for all alternatives.

Overall Effective Discharge Trends

Given the sensitivity to flows rates and sediment transport calculations, significant variability was observed in effective discharge. As a general rule, the calculated effective discharge flow increased at both sites where diversions and flows are expected to increase. Trends in the recurrence interval of effective discharge generally suggest that effective discharge will occur less frequently in areas with decreased flows and more frequently in areas with increased flows, however there are many exceptions to the general trend.

4.6.3.10 Impact Summary

Predicted impacts to channel morphology were estimated based on a combination of observation of existing conditions, assessment of existing physical data and the numerical assessments presented above. Predicted impacts were made based on observed data trends amongst the various analyses. These predicted impacts are presented for the different river basins below.

4.6.3.10.1 Fraser River Basin

Existing physical data suggests that current diversion practices have not caused significant changes in channel morphology throughout a majority of the Fraser River Basin. This conclusion is based on direct site observations and conclusions from the stream gage analysis and the cross section data from the Fraser River showing no systematic aggradation or degradation. Aerial photo data suggests that streams in the basin are widening, however these calculated results are not supported by the remainder of the data.

The exception to the conclusion that morphologic changes are not occurring in the Fraser River Basin are the areas below diversions with no bypass flows. Observations of these locations suggest that more pronounced vegetative encroachment and sediment aggradation may be occurring in these areas.

Numerical analysis of Current Conditions (2006) quantifies various parameters related to the stream segments that describe the magnitude and frequency of different events that impact channel morphology and provide a basis for comparing impacts of Project alternatives with RFFAs.

Representative Sites FR1 and FR5

Representative sites FR1 and FR5 are located near the upper end of the Fraser River below Denver Water's diversion and modeled results for these sites were similar. Flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.8 years at both sites with Phase 2 transport occurring approximately 10 days per year at each location. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 5 years at both locations. Effective discharge is predicted to occur with a recurrence interval of approximately 3-4 years at these sites. The relatively low recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at these stream segments are not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at these locations by approximately 10% and sediment supply by 9%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.8-1.9 years with flows above the threshold for Phase 2 transport occurring approximately 8-10 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 5 years at both locations. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5-6 years at these sites given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 9-10 years for this alternative. Effective discharge is predicted to occur approximately once every 5-7 years at these locations given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at FR1 and FR5 are considered insignificant and no changes in channel morphology are predicted at these locations.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at these locations by approximately 20% and sediment supply by 16%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.8 to 2 years with flows above the threshold for Phase 2 transport occurring approximately 7-9 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be between 5 and 6 years at these locations. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at these sites given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10-12 years for this alternative. Effective discharge is predicted to occur approximately once every 7 years at these locations given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are considered insignificant and no changes in channel morphology are predicted at these locations.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at these locations by approximately 50% and sediment supply by 38%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.8 to 2.7 years with flows above the threshold for Phase 2 transport occurring approximately 4-7 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be between 8 and 9 years at these locations. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 8-9 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 18 years for this alternative. Effective discharge is predicted to occur approximately once every 12 years at these locations given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be greater than the Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to be up to 1 year greater than for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur less frequently for the Proposed Action with RFFAs. Based on results it is predicted that flow reductions will result in longer duration and additional locations where sediment may temporarily accumulate when compared to Current Conditions (2006). Given the relative frequency of Phase 2 transport; however, sediment deposition is predicted to be temporary and no long-term changes in channel morphology are predicted at these locations.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at these locations by approximately 49% and sediment supply by 37%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 2.4 to 2.6 years with flows above the threshold for Phase 2 transport occurring approximately 4 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 7 years at these locations. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 8-9 years at these sites given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 17-18 years for this alternative. Effective discharge is predicted to occur approximately once every 12-13 years at these locations given Alternative 8a. Overall impacts of Alternative 8a are predicted to be very similar to the Proposed Action with RFFAs. Based on results it is predicted that flow reductions will result in longer duration and additional locations where sediment may temporarily accumulate when compared to Current Conditions (2006). Given the relative frequency of Phase 2 transport; however, sediment deposition is predicted to be temporary and no long-term changes in channel morphology are predicted at these locations.

Representative Site FR2

Representative Site FR2 is located on the Fraser River downstream of Tabernash. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.4 years with Phase 2 transport occurring approximately 27 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 2 years. Effective discharge is predicted to occur with a recurrence interval of approximately 4 years. The relatively low recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at this stream segment is not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 5% and sediment supply by 9%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.4 years with flows above the threshold for Phase 2 transport occurring approximately 26 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 6 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at FR2 is considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 11% and sediment supply by 17%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.4 years with flows above the threshold for Phase 2 transport occurring approximately 24 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 3 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and the No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 32% and sediment supply by 41%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.5 years with flows above the threshold for Phase 2 transport occurring approximately 20 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 2.5 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 8 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 12 years for this alternative. Effective discharge is predicted to occur approximately once every 4 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be greater than the Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur less frequently for the Proposed Action with RFFAs. Based on results it is predicted that flow reductions could result in more temporary sediment accumulation when compared to Current Conditions (2006). Given that the recurrence interval of Phase 2 transport is relatively unchanged and Phase 2 transport is still predicted to occur for approximately 20 days per year, no long-term changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 31% and sediment supply by 39%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.5 years with flows above the threshold for Phase 2 transport occurring approximately 21 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 2.5 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 8 years at these sites given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 12 years for this alternative. Effective discharge is predicted to occur approximately once every 9 years at this location given Alternative 8a with RFFAs. Overall differences between

Current Conditions (2006) and Alternative 8a are predicted to be similar to the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur less frequently for Alternative 8a. Based on analysis results it is predicted that flow reductions could result in more temporary sediment accumulation when compared to Current Conditions (2006). Given that the recurrence interval of Phase 2 transport is relatively unchanged and Phase 2 transport is still predicted to occur for approximately 21 days per year, no long-term changes in channel morphology are predicted at this location.

Representative Site FR3

Representative Site FR3 is located on St. Louis Creek downstream of Denver Water's diversion. For Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.4 years with Phase 2 transport occurring approximately 23 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 2.5 years. Effective discharge is predicted to occur with a recurrence interval of approximately 3 years. The relatively low recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at this stream segment is not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 4% and sediment supply by 3%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.4 years with flows above the threshold for Phase 2 transport occurring approximately 22 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2.5 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 3 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at FR3 are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 9% and sediment supply by 6%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.5 years with flows above the threshold for Phase 2 transport occurring approximately 20 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2.5 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given the No Action Alternative; a Current

Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 3 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 35% and sediment supply by 18%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.6 years with flows above the threshold for Phase 2 transport occurring approximately 15 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 3 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 12 years for this alternative. Effective discharge is predicted to occur approximately once every 4 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be greater than the Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur slightly less frequently for the Proposed Action with RFFAs. Given that the recurrence interval of Phase 2 transport is relatively unchanged and Phase 2 transport is still predicted to occur for approximately 15 days per year, no long-term changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 33% and sediment supply by 27%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.6 years with flows above the threshold for Phase 2 transport occurring approximately 16 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 3 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 12 years for this alternative. Effective discharge is predicted to occur approximately once every 4 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are predicted to be similar to the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur slightly less frequently for Alternative 8a. Based on analysis results it is predicted that flow reductions could result in more temporary sediment accumulation when compared to Current Conditions (2006). Given that the recurrence interval of Phase 2 transport is relatively unchanged and Phase 2 transport is still predicted to occur for approximately 15 days per year, no long-term changes in channel morphology are predicted at this location.

Representative Site FR4

Representative Site FR4 is located on Ranch Creek downstream of Denver Water's diversion. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.3 years with Phase 2 transport occurring approximately 20 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 2 years. Effective discharge is predicted to occur with a recurrence interval of approximately 3 years. The relatively low recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at this stream segment is not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 2% and sediment supply by 3%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.3 years with flows above the threshold for Phase 2 transport occurring approximately 20 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 3 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at FR4 is considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 5% and sediment supply by 6%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.3 years with flows above the threshold for Phase 2 transport occurring approximately 18 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 5 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 22% and sediment supply by 22%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.4 years with flows above the threshold for Phase 2 transport occurring approximately 13 days per year. The maximum duration between flow events large enough to initiate

Phase 2 transport is predicted to be approximately 3 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 5 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be greater than the Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events are predicted to occur at the same frequency as they do for Current Conditions (2006) and effective flows are predicted to occur slightly less frequently for the Proposed Action with RFFAs. Given that the recurrence interval of Phase 2 transport is relatively unchanged and Phase 2 transport is still predicted to occur for approximately 13 days per year, no long-term changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 20% and sediment supply by 19%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.4 years with flows above the threshold for Phase 2 transport occurring approximately 14 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 3 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at these sites given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 3 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are predicted to be similar to the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur at the same frequency for Alternative 8a with RFFAs as they do for Current Conditions (2006). Based on analysis results it is predicted that flow reductions could result in more temporary sediment accumulation when compared to Current Conditions (2006). Given that the recurrence interval of Phase 2 transport remains relatively unchanged and Phase 2 transport is still predicted to occur for approximately 14 days per year, no long-term changes in channel morphology are predicted at this location.

Representative Site FR6

Representative Site FR6 is located immediately downstream of Denver Water's diversion on Jim Creek. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport is predicted to occur with a recurrence interval of approximately 25 years with Phase 2 transport rarely occurring (approximately 0.2 days per year). Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 28 years. Effective discharge is predicted to occur with a recurrence interval of approximately 11 years. The high recurrence interval for Phase 2 transport, the infrequency at which flows reach this threshold and the high recurrence interval for effective discharge suggest that this stream segment is currently impacted by diversions and changes in channel morphology have occurred. This supports observations that vegetative encroachment is likely occurring at this location.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Flow changes resulting from Full Use of the Existing System with RFFAs are predicted to decrease the bedload sediment transport capacity at this location by approximately 13% and decrease sediment supply by 10%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 22 years with flows above the threshold for Phase 2 transport rarely occurring (approximately 0.2 day per year). The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 26 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 8 years for this alternative. Effective discharge is predicted to occur approximately once every 8 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at FR6 are considered insignificant. Predicted flows will not be sufficient to maintain an equilibrium and current aggradation and/or vegetative encroachment is likely to persist.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 18% and sediment supply by 23%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 24 years with flows above the threshold for Phase 2 transport rarely occurring (approximately 0.2 day per year). The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 31 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 7 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 9 years for this alternative. Effective discharge is predicted to occur approximately once every 9 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location. Predicted flows will not be sufficient to maintain an equilibrium and current aggradation and/or vegetative encroachment is likely to persist.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 56% and sediment supply by 46%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 27 years with flows above the threshold for Phase 2 transport rarely occurring (approximately 0.1 day per year). The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 31 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 9 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 14 years for this alternative. Effective discharge is predicted to occur approximately once every 14 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be slightly greater than the Full Use of the Existing System or the No Action Alternative. Slight reductions to the frequency and recurrence of Phase 2 transport flows are not predicted to notably change morphology at this location given the already low frequency of these events. Reductions in the frequency of peak 5- and 10-year flood events when compared to Current Conditions (2006) suggest that existing aggradation and vegetative encroachment may be accelerated.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 55% and sediment supply by 45%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 27 years with flows above the threshold for Phase 2 transport rarely occurring (approximately 0.1 days per year). The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 31 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 9 years at these sites given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 14 years for this alternative. Effective discharge is predicted to occur approximately once every 14 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are predicted to be similar to the Proposed Action with RFFAs. Slight reductions to the frequency and recurrence of Phase 2 transport flows are not predicted to notably change morphology at this location given the already low frequency of these events. Reductions in the frequency of peak 5- and 10-year flood events when compared to Current Conditions (2006) suggest that existing aggradation and vegetative encroachment may be accelerated.

Representative Site FR7

Representative Site FR7 is located upstream of Denver Water's diversion on Vasquez Creek. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.2 years with Phase 2 transport occurring approximately 16 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 1.5 years. Effective discharge is predicted to occur with a recurrence interval of approximately 1.2 years. The recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at this stream segment is not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Increased flows resulting from Full Use of the Existing System with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 6% and sediment supply by 4%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.2 years with flows above the threshold for Phase 2 transport occurring approximately 17 days per year. Flow events large enough to initiate Phase 2 transport are predicted to occur every year.

The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.2 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at FR7 is considered insignificant and no changes in channel morphology are predicted at this location.

Increased flows resulting from the No Action Alternative are predicted to increase the bedload sediment transport capacity at this location by approximately 11% and sediment supply by 5%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.3 years with flows above the threshold for Phase 2 transport occurring approximately 18 days per year. Flow events large enough to initiate Phase 2 transport are predicted to occur every year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 8 years for this alternative. Effective discharge is predicted to occur approximately once every 2 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and the No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Increased flows resulting from the Proposed Action with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 37% and sediment supply by 12%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 23 days per year. Flow events large enough to initiate Phase 2 transport are predicted to occur every year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 7 years for this alternative. Effective discharge is predicted to occur approximately once every 1.5 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be greater than the Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring somewhat more frequently. Peak flood events are predicted to occur at a similar frequency as they do for Current Conditions (2006) and effective flows are predicted to occur slightly less frequently for the Proposed Action with RFFAs. Given that the recurrence interval of Phase 2 transport is basically unchanged and Phase 2 transport is still predicted to occur a similar number of days per year, no long-term changes in channel morphology are predicted at this location.

Increased flows resulting from Alternative 8a with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 32% and sediment supply by 11%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately

22 days per year. Flow events large enough to initiate Phase 2 transport are predicted to occur every year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 8 years for this alternative. Effective discharge is predicted to occur approximately once every 1.1 years at this location given Alternative 8a with RFFAs. Overall conditions for Alternative 8a are predicted to be similar to conditions for the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring somewhat more frequently. Peak flood events are predicted to occur at a similar frequency as they do for Current Conditions (2006) and effective flows are predicted to occur slightly more frequently for Alternative 8a. Given that the recurrence interval of Phase 2 transport remains relatively unchanged and Phase 2 transport is still predicted to occur a similar number of days per year, no long-term changes in channel morphology are predicted at this location.

Overall Conclusions for the Fraser River Basin

Results generated from the Representative sites in the Fraser River Basin were used to predict impacts throughout the basin. Based on the results presented, a majority of the stream systems appear to be stable from a channel morphology standpoint. Altered flows resulting from Full Use of the Existing System and the No Action Alternative are not expected to cause any notable changes in morphology. Flow changes for the Proposed Action and Alternative 8a with RFFAs are, in general, greater than the flow changes predicted for other Project alternatives. It is expected that additional localized sediment deposition could occur given these alternatives with RFFAs; however results indicate that remaining flows are sufficient to continue to cause Phase 2 transport and peak flood events to occur frequently therefore no long-term changes in channel morphology are predicted.

Streams below diversions with no bypass requirements were found to be an exception to the conclusions reached for the remainder of the drainage. In areas with no bypass flows, peak flows have already been reduced to the point where Phase 2 sediment transport does not occur often enough and aggradation and/or channel encroachment is likely already occurring. Full Use of the Existing System and the No Action Alternative provide conditions that are generally similar to Current Conditions (2006) so no changes are expected given these alternatives. Flow reductions resulting from the Proposed Action and Alternative 8a with RFFAs may cause on-going aggradation and/or vegetative encroachment to accelerate.

4.6.3.10.2 Williams Fork River Basin

Existing physical data suggests that current diversion practices have not caused significant changes in channel morphology throughout the Williams Fork River Basin. This conclusion is based on direct site observations and conclusions from the stream gage showing no systematic aggradation or degradation.

Numerical analysis of Current Conditions (2006) quantifies various parameters related to the stream segments that describe the magnitude and frequency of different events that impact channel morphology and provide a basis for comparing impacts of Project alternatives with RFFAs.

Representative Site WF1

Representative Site WF1 is the downstream site on the Williams Fork River. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.1 years with Phase 2 transport occurring approximately 32 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 2 years. Effective discharge is predicted to occur with a recurrence interval of approximately 1.6 years. The relatively low recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at this stream segment is not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 3% and sediment supply by 4%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 31 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.6 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at WF1 is considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 6% and sediment supply by 7%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.2 years with flows above the threshold for Phase 2 transport occurring approximately 30 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.9 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 18% and sediment supply by 17%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.2 years with flows above the threshold for Phase 2 transport occurring approximately 26 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 2 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be slightly greater than the Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events are not predicted to change when compared to Current Conditions (2006) and effective flows are predicted to occur slightly less frequently for the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 17% and sediment supply by 16%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.2 years with flows above the threshold for Phase 2 transport occurring approximately 27 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at these sites given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.8 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are predicted to be similar to the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events are not predicted to change when compared to Current Conditions (2006) and effective flows are predicted to occur slightly less frequently for Alternative 8a. Overall differences between Current Conditions (2006) and Alternative 8a are considered insignificant and no changes in channel morphology are predicted at this location.

Representative Site WF2

Representative Site WF2 is the upstream site on the Williams Fork River located below Steelman Creek. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.2 years with Phase 2 transport occurring approximately 26 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 2 years. Effective discharge is predicted to occur with a recurrence interval of approximately 1.4 years. The relatively low recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at this stream segment is not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 6% and sediment supply by 10%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.2 years with flows above the threshold for Phase 2 transport occurring approximately 25 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.4 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at WF2 are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 9% and sediment supply by 14%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.2 years with flows above the threshold for Phase 2 transport occurring approximately 24 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 3 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and the No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 24% and sediment supply by 29%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.3 years with flows above the threshold for Phase 2 transport occurring approximately 18 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 2 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be slightly greater than the Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current

Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events are not predicted to change when compared to Current Conditions (2006) and effective flows are predicted to occur slightly less frequently for the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 22% and sediment supply by 26%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.3 years with flows above the threshold for Phase 2 transport occurring approximately 19 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 2 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at these sites given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.6 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are predicted to be similar to the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events are not predicted to change when compared to Current Conditions (2006) and effective flows are predicted to occur slightly less frequently for Alternative 8a. Overall differences between Current Conditions (2006) and Alternative 8a are considered insignificant and no changes in channel morphology are predicted at this location.

Overall Conclusions for the Williams Fork River Basin

Results generated from the Representative sites in the Williams Fork River Basin were used to predict impacts throughout the basin. Based on results, stream systems appear to be stable from a channel morphology standpoint. Altered flows resulting from Full Use of the Existing System and the No Action Alternative are not expected to cause any notable changes in morphology. Flow changes for the Proposed Action and Alternative 8a with RFFAs are in general, greater than the flow changes predicted for other Project alternatives with RFFAs; however, changes in the recurrence interval of Phase 2 transport and the frequency of Phase 2 transport are not predicted to change significantly. No changes to the recurrence of peak flood flows are expected for any alternative therefore no changes in channel morphology are predicted.

4.6.3.10.3 Colorado River Basin

Existing physical data suggests that current diversion practices have not caused significant changes in channel morphology throughout the Colorado River. This conclusion is based on direct site observations and conclusions from the stream gage showing no systematic aggradation or degradation, although slight aggradation may be occurring near the Kremmling gage based on the analysis of gage data. Aerial photo data suggests that streams in the basin are widening, however these calculated results are not supported by the remainder of the data.

Numerical analysis of Current Conditions (2006) quantifies various parameters related to the stream segments that describe the magnitude and frequency of different events that impact channel morphology and provide a basis for comparing impacts of Project alternatives with RFFAs.

Representative Site CR1

Representative Site CR1 is located on the Colorado River upstream of the confluence with the Williams Fork. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 9 years with Phase 2 transport occurring approximately 2 days per year based on results developed using the Parker and Wilcock and Crowe equations. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 17 years. Given Current Conditions (2006) a flow of approximately 600 cfs occurs with a recurrence interval of 1.5-years and may be a better indicator of when Phase 2 transport actually occurs based on the questionable results obtained using the Parker and Wilcock and Crowe equations. Effective discharge is predicted to occur with a recurrence interval of approximately 7 years. Data suggests that sediment deposition likely occurs during years between peak events. Sediment deposition is believed to be temporary with aggraded material removed during peak flow years.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 6% and sediment supply by 14%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 8 years with flows above the threshold for Phase 2 transport occurring approximately 2 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 18 years from these equations. A flow of approximately 600 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 1.9 years given Full Use of the Existing System. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 9 years for this alternative. Effective discharge is predicted to occur approximately once every 8 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at CR1 are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 9% and sediment supply by 16%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 8 years with flows above the threshold for Phase 2 transport occurring approximately 2 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 18 years at this location from these equations. A flow of approximately 600 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 2.0 years given the No Action Alternative. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 9 years for this alternative. Effective discharge is predicted to occur approximately once every 9 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 18% and sediment supply by 20%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 8 years with flows above the threshold for Phase 2 transport occurring approximately 2 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 18 years at this location from these equations. A flow of approximately 600 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 2.0 years given the Proposed Action with RFFAs. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 8 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 9 years for this alternative. Effective discharge is predicted to occur approximately once every 9 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 16% and sediment supply by 20%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 8 years with flows above the threshold for Phase 2 transport occurring approximately 2 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 18 years at this location from these equations. A flow of approximately 600 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 2.0 years given Alternative 8a with RFFAs. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 8 years at these sites given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 9 years for this alternative. Effective discharge is predicted to occur approximately once every 8 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are considered insignificant and no changes in channel morphology are predicted at this location.

Representative Site CR2

Representative Site CR2 is located on the Colorado River downstream of the confluence with the Williams Fork. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 3 years with Phase 2 transport occurring approximately 11 days per year based on results developed using the Parker and Wilcock and Crowe equations. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 8 years. Given Current Conditions (2006) a flow of approximately 800 cfs occurs with a recurrence interval of 1.5-years and may be a better indicator of when Phase 2 transport actually occurs based on the questionable results obtained using the Parker and Wilcock and Crowe equations. Effective discharge is predicted to occur with a recurrence interval of approximately 9 years. Data suggests that sediment deposition may occur during years between peak events, but not to the extent or for the duration anticipated upstream of the Williams Fork confluence. Sediment deposition is expected to be temporary with aggraded material removed during peak flow years.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are not predicted to reduce the bedload sediment transport capacity at this location while sediment supply is predicted to be reduced by 5%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 3.5 years with flows above the threshold for Phase 2 transport occurring approximately 9 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 8 years from these equations. A flow of approximately 800 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 1.4 years given Full Use of the Existing System with RFFAs. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 7 years for this alternative. Effective discharge is predicted to occur approximately once every 7 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System at CR2 is considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 3% and sediment supply by 6%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 3.5 years with flows above the threshold for Phase 2 transport occurring approximately 9 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 8 years at this location from these equations. A flow of approximately 800 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 1.4 years given the No Action Alternative. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 7 years for this alternative. Effective discharge is predicted to occur approximately once every 8 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 11% and sediment supply by 10%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 3.5 years with flows above the threshold for Phase 2 transport occurring approximately 7 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 9 years at this location from these equations. A flow of approximately 800 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 1.5 years given the Proposed Action with RFFAs. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 8 years for this alternative. Effective discharge is predicted to occur approximately once every 8 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are considered insignificant and no changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 9% and sediment supply by 9%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 3.5 years with flows above the threshold for Phase 2 transport occurring approximately 7 days per year based on the Parker and Wilcock and Crowe equations. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 9 years at this location from these equations. A flow of approximately 800 cfs which has a recurrence interval of 1.5 based on Current Conditions (2006) is expected to occur with a recurrence interval of 1.5 years given Alternative 8a with RFFAs. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 6 years at this site given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 8 years for this alternative. Effective discharge is predicted to occur approximately once every 8 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are considered insignificant and no changes in channel morphology are predicted at this location.

Overall Conclusions for the Colorado River Basin

Results generated from the Representative sites in the Colorado River were used to predict impacts along the river. Based on results, stream systems appear to be stable from a channel morphology standpoint, however sediment deposition likely occurs during years where peak flows are lower as the recurrence interval of Phase 2 transport is lengthened, particularly upstream of the Williams Fork confluence. Altered flows resulting from Full Use of the Existing System and the No Action Alternative are not expected to cause any notable changes in morphology. Flow changes for the Proposed Action and Alternative 8a with RFFAs are in general, greater than the flow changes predicted for other Project alternatives with RFFAs; however, changes in the recurrence interval of Phase 2 transport and the frequency of Phase 2 transport are not predicted to change significantly. The analysis based in the 1.5-year recurrence interval flow for Current Conditions (2006) shows that this magnitude flood will still occur at approximately the same frequency both upstream and downstream of the Williams Fork confluence for all Project alternatives with RFFAs. The recurrence interval of the 5-year flood based on Current Conditions (2006) hydrology is expected to increase given flow changes; however the recurrence interval for the 10-year flood is expected to decrease for all Project alternatives with RFFAs. Given the slight differences calculated, no measurable changes in channel morphology are predicted for any of the alternatives with RFFAs.

4.6.3.10.4 Blue River Basin

Existing physical data suggests that current diversion practices have not caused significant changes in channel morphology throughout the Blue River. This conclusion is based on direct site observations. Aerial photo data supports this conclusion for the Blue River.

Numerical analysis of Current Conditions (2006) quantifies various parameters related to the stream segments that describe the magnitude and frequency of different events that impact channel morphology and provide a basis for comparing impacts of Project alternatives with RFFAs.

Representative Site BR1

Representative Site BR1 is located on the Blue River between Dillon and Green Mountain Reservoirs, downstream of Boulder Creek. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.5 years with Phase 2 transport occurring approximately 19 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 3.5 years. Effective discharge is predicted to occur with a recurrence interval of approximately 3 years. The relatively low recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the limited number of years between Phase 2 events and the recurrence interval for effective discharge suggest that channel morphology at this stream segment is not currently impacted by diversions.

Changes in flows resulting from the different Project alternatives with RFFAS will alter some of the parameters related to channel morphology. Reduced flows resulting from Full Use of the Existing System with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 25% and sediment supply by 17%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.8 years with flows above the threshold for Phase 2 transport occurring approximately 14 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 5 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 8 years at this site given Full Use of the Existing System with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 12 years for this alternative. Effective discharge is predicted to occur approximately once every 5 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System were quantified. The recurrence interval of Phase 2 transport is predicted to be similar to that for Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur less frequently for Full Use of the Existing System. Based on results it is predicted that flow reductions could result in more temporary sediment accumulation when compared to Current Conditions (2006). Given that the recurrence interval of Phase 2 transport is basically unchanged and Phase 2 transport is still predicted to occur for approximately 14 days per year, no long-term changes in channel morphology are predicted at this location.

Reduced flows resulting from the No Action Alternative are predicted to reduce the bedload sediment transport capacity at this location by approximately 35% and sediment supply by 23%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 2.4 years with flows above the threshold for Phase 2 transport occurring approximately 12 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 6.5 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 13 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 19 years for this alternative. Effective discharge is predicted to occur approximately once every 9 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and No Action Alternative are greater than any other Project alternative with RFFAs. The recurrence interval of Phase 2 transport is predicted to be about 1 year greater than Current Conditions (2006) with Phase 2 transport flows occurring less frequently although they are still predicted to occur for multiple days per year. Peak flood events and effective flows are predicted to occur less frequently for the No Action Alternative with the current 5- and 10-year flows projected to occur once every 13 and 19 years, respectively. It is predicted that flow reductions will result in longer duration and addition locations where sediment may temporarily accumulate when compared to Current Conditions (2006). Given the relative frequency of Phase 2 transport; however, sediment deposition is predicted to be temporary and no long-term changes in channel morphology are predicted at these locations.

Reduced flows resulting from the Proposed Action with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 30% and sediment supply by 20%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.8 years with flows above the threshold for Phase 2 transport occurring approximately 12 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 5 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 7 years at these sites given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 12 years for this alternative. Effective discharge is predicted to occur approximately once every 6 years at this location given the Proposed Action with RFFAs. Overall differences between Current Conditions (2006) and the Proposed Action with RFFAs are predicted to be similar to those for Full Use of the Existing System. It is predicted that flow reductions could result in more temporary sediment accumulation when compared to Current Conditions (2006). Given that the recurrence interval of Phase 2 transport remains relatively unchanged and Phase 2 transport is still predicted to occur for approximately 12 days per year, no changes in channel morphology are predicted at this location.

Reduced flows resulting from Alternative 8a with RFFAs are predicted to reduce the bedload sediment transport capacity at this location by approximately 29% and sediment supply by 20%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.8 years with flows above the threshold for Phase 2 transport occurring approximately 13 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be approximately 5 years at this location. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 7 years at this site given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 12 years for this alternative. Effective discharge is predicted to occur approximately once every 5 years at this location given Alternative 8a with RFFAs. Overall differences between Current Conditions (2006) and Alternative 8a are predicted to be similar to those for Full Use of the Existing System and the Proposed Action with RFFAs. It is predicted that flow reductions could result in more temporary sediment accumulation when compared to Current Conditions (2006). Given that the recurrence interval of Phase 2 transport is basically unchanged and Phase 2 transport is still predicted to occur for approximately 12 days per year, no changes in channel morphology are predicted at this location.

Overall Conclusions for the Blue River Basin

Results generated from the Representative sites on the Blue River were used to predict impacts throughout the stream. Based on these results, stream systems appear to be stable from a channel morphology standpoint. Altered flows resulting from Full Use of the Existing System and the Proposed Action and Alternative 8a with RFFAs are not expected to cause any notable changes in channel morphology. Flow changes for the No Action Alternative are in general, greater than the flow changes predicted for other Project alternatives with RFFAs; however changes in the recurrence interval of Phase 2 transport and the frequency of Phase 2 transport are not predicted to change significantly. Peak flood events and effective flows are predicted to occur less frequently for the No Action Alternative with the current 5- and 10-year flows projected to occur once every 13 and 19 years, respectively. This data suggests that sediment deposition will likely occur during years between peak events given the No Action Alternative. Sediment deposition is believed to be temporary with aggraded material removed during peak flow years.

4.6.3.10.5 North Fork South Platte River Basin

Existing physical data suggests that current diversion practices have not caused significant changes in channel morphology throughout the North Fork South Platte River, although channel armoring has been deployed at locations to arrest and/or prevent bank erosion. This conclusion is based on direct site observations.

Numerical analysis of Current Conditions (2006) quantifies various parameters related to the stream segments that describe the magnitude and frequency of different events that impact channel morphology and provide a basis for comparing impacts of Project alternatives with RFFAs.

Representative Site NF1

Representative Site NF1 is located on the North Fork downstream of the Roberts Tunnel outlet near the Town of Shawnee. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 2 years with Phase 2 transport occurring approximately 10 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 6 years. Effective discharge is predicted to occur with a recurrence interval of approximately 1.4 years. The recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the number of years between Phase 2 events and the recurrence interval for effective discharge are similar at this location to sites where flow depletions have occurred suggesting that excluding localized bank instabilities that have been addressed through bank stabilization, channel morphology at this stream segment is generally unimpacted by increased flows.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Increased flows resulting from Full Use of the Existing System with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 99% and sediment supply by 32%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 23 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 3 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given Full Use of the Existing System with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 4 years for this alternative. Effective discharge is predicted to occur approximately once every 1.1 years at this location given Full Use of the Existing System. Overall flow increases are predicted to encourage additional transport. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring more than twice as often. Peak flood events and effective flows are predicted to occur more frequently for Full Use of the Existing System. Based on these results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from the No Action Alternative are predicted to increase the bedload sediment transport capacity at this location by approximately 142% and sediment supply by 44%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 28 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 1.5 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 2 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 3 years for this alternative. Effective discharge is predicted to occur approximately once every 1.2 years at this location given the No Action Alternative. Overall flow increases are predicted to encourage additional transport slightly more than for Full Use of the Existing System. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring approximately three times as often. Peak flood events and effective flows are predicted to occur more frequently for the No Action Alternative. Based on results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from the Proposed Action with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 196% and sediment supply by 42%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 34 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 1.5 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 2 years at this site given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 3 years for this alternative. Effective discharge is predicted to occur approximately once every 1.2 years at this location given the Proposed Action with RFFAs. Overall flow increases are predicted to encourage additional transport slightly more than for the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring more than three times as often. Peak flood events and effective flows are predicted to occur more frequently for the Proposed Action with RFFAs. Based on results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from Alternative 8a with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 193% and sediment supply by 42%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 33 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 1.5 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 2 years at this site given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 3 years for this alternative. Effective discharge is predicted to occur approximately once every 1.2 years at this location given Alternative 8a with RFFAs. Overall flow increases are predicted to encourage additional transport in a similar manner as the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring more than three times as often. Peak flood events and effective flows are predicted to occur more frequently for Alternative 8a. Based on results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Representative Reach NF2

Representative Site NF2 is located on the North Fork near the Town of Pine. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 1.5 years with Phase 2 transport occurring approximately 27 days per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 flows is 4 years. Effective discharge is predicted to occur with a recurrence interval of approximately 1.5 years. The recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the number of years between Phase 2 events and the recurrence interval for effective discharge as similar at this location to sites where flow depletions have occurred suggest that excluding localized bank instabilities that have been addressed through bank stabilization, channel morphology at this stream segment is generally unimpacted by increased flows.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Increased flows resulting from Full Use of the Existing System with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 47% and sediment supply by 46%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.2 years with flows above the threshold for Phase 2 transport occurring approximately 46 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 2 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.1 years at this location given Full Use of the Existing System. Overall flow increases are predicted to encourage additional transport. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring nearly twice as often. The recurrence interval of peak flood events is predicted to remain unchanged while effective flows are predicted to occur more frequently for Full Use of the Existing System. Based on results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from the No Action Alternative are predicted to increase the bedload sediment transport capacity at this location by approximately 66% and sediment supply by 63%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 51 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 1 year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.1 years at this location given the No Action Alternative. Overall flow increases are predicted to encourage additional transport slightly more than for Full Use of the Existing System. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring approximately two times as often. The recurrence interval of peak flood events is predicted to remain unchanged while effective flows are predicted to occur more frequently for the No Action Alternative. Based on results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from the Proposed Action with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 88% and sediment supply by 75%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 59 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 1 year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.1 years at this location given the Proposed Action with RFFAs. Overall flow increases are predicted to encourage additional transport slightly more than for the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring approximately three times as often. The recurrence interval of peak flood events is predicted to remain unchanged while effective flows are predicted to occur more frequently for the Proposed Action with RFFAs. Based on these results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from Alternative 8a with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 86% and sediment supply by 74%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 1.1 years with flows above the threshold for Phase 2 transport occurring approximately 58 days per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 1 year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.1 years at this location given Alternative 8a with RFFAs. Overall flow increases are predicted to encourage additional transport in a similar manner as the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to decrease when compared to Current Conditions (2006) with Phase 2 transport flows occurring approximately three times as often. The recurrence interval of peak flood events is predicted to remain unchanged while effective flows are predicted to occur more frequently for Alternative 8a. Based on these results it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006).

Overall Conclusions for the North Fork South Platte River Basin

Results generated from the Representative sites on the North Fork South Platte were used to predict impacts throughout the stream. Based on the results of this analysis, the stream system appears to be stable from a channel morphology standpoint, although past channel stabilization activities indicates past bank erosion. Altered flows resulting from the Project alternatives with RFFAs will increase flows throughout this area. The Phase 2 sediment transport recurrence interval for all Project alternatives with RFFAs will be 1.1-1.2 years, which is a decrease in the recurrence interval for Current Conditions (2006). Flows are expected to be at or above the threshold causing Phase 2 sediment transport approximately 2-3 times more often for the different alternatives with RFFAs than they are for Current Conditions (2006). The recurrence intervals for peak flood events and effective discharge are also expected to increase for all alternatives in upper segments while the recurrence of peak flows are predicted to remain unchanged further downstream. Changes are predicted to encourage bank instabilities and additional localized bank stabilization may be required. Of the various Project alternatives with RFFAs, Full Use of the Existing System is predicted to have the least impact while the Proposed Action and Alternative 8a with RFFAs are predicted to have the greatest impacts.

4.6.3.10.6 South Boulder Creek Basin

Existing physical data suggests that current diversion practices have not caused significant changes in channel morphology throughout South Boulder Creek, although channel armoring has been deployed at locations to arrest and/or prevent bank erosion. This conclusion is based on direct site observations.

Numerical analysis of Current Conditions (2006) quantifies various parameters related to the stream segments that describe the magnitude and frequency of different events that impact channel morphology and provide a basis for comparing impacts of Project alternatives with RFFAs.

Representative Site SBC1

Representative Site SBC1 is located on South Boulder Creek upstream of Rollinsville. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur with a recurrence interval of approximately 4 years with Phase 2 transport occurring approximately 1 day per year. Based on the modeled 45 year daily PACSM results, the longest interval between flows large enough to initiate Phase 2 transport is 17 years. Effective discharge is predicted to occur with a recurrence interval of approximately 1.5 years. Recurrence interval of Phase 2 transport and effective discharge are similar to recurrence intervals for the same parameters at locations where flow depletions have occurred. The frequency of Phase 2 transport is less and the maximum time period between Phase 2 flows is greater than unimpacted sites. Observations that the channel bed at this site is heavily armored likely impact these values.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Increased flows resulting from Full Use of the Existing System with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 4% and sediment supply by 4%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 4 years with flows above the threshold for Phase 2 transport occurring approximately 1 day per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 17 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 5 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.5 years at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System are considered insignificant and no changes in channel morphology are predicted at this location.

Increased flows resulting from the No Action Alternative are predicted to increase the bedload sediment transport capacity at this location by approximately 9% and sediment supply by 7%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 4 years with flows above the threshold for Phase 2 transport occurring approximately 1 day per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 14 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 3 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and the No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Increased flows resulting from the Proposed Action with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 43% and sediment supply by 18%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 3 years with flows above the threshold for Phase 2 transport occurring approximately 1 day per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 7 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is predicted to occur every 7 years for this alternative. Effective discharge is predicted to occur approximately once every 2 years at this location given the Proposed Action with RFFAs. Overall flow increases are predicted to encourage additional transport slightly more than for Current Conditions (2006), Full Use of the Existing System or the No Action Alternative. The recurrence interval of Phase 2 transport is predicted to decrease slightly when compared to these alternatives although Phase 2 transport flows are expected to occur with the same, low frequency. Peak flood events and effective flows are predicted to occur somewhat more frequently. Based on results it is predicted that increased flows will continue to cause erosive forces that may increase the need for additional localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from Alternative 8a with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 39% and sediment supply by 17%. Phase 2 sediment transport is predicted to occur with a recurrence interval of 3 years with flows above the threshold for Phase 2 transport occurring approximately 1 day per year. The maximum duration between flow events large enough to initiate Phase 2 transport is predicted to be 7 years. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given Alternative 8a with RFFAs; a Current Conditions

(2006) 10-year flood is predicted to occur every 7 years for this alternative. Effective discharge is predicted to occur approximately once every 1.4 years at this location given Alternative 8a with RFFAs. Overall flow increases are predicted to encourage additional transport in a similar manner as the Proposed Action with RFFAs. The recurrence interval of Phase 2 transport is predicted to decrease slightly when compared to these alternatives although Phase 2 transport flows are expected to occur with the same, low frequency. Peak flood events and effective flows are predicted to occur somewhat more frequently. Based on results it is predicted that increased flows will continue to cause erosive forces that may increase the need for additional localized bank stabilization when compared to Current Conditions (2006).

Representative Site SBC3

Representative Site SBC3 is located on South Boulder Creek downstream of Gross Reservoir. Under Current Conditions (2006) flows required to initiate Phase 2 sediment transport are predicted to occur every year with Phase 2 transport occurring approximately 47 days per year. Based on the modeled 45 year daily PACSM results, Phase 2 transport is predicted to occur every year. Effective discharge is predicted to occur every year. Recurrence interval of Phase 2 transport, the frequency at which flows reach this threshold, the number of years between Phase 2 events and the recurrence interval for effective discharge all suggest that high flows encourage transport at this location.

Changes in flows resulting from the different Project alternatives with RFFAs will alter some of the parameters related to channel morphology. Increased flows resulting from Full Use of the Existing System with RFFAs are predicted to increase the bedload sediment transport capacity at this location by approximately 15% and sediment supply by 3%. Phase 2 sediment transport is predicted to occur every year with flows above the threshold for Phase 2 transport occurring approximately 53 days per year. Phase 2 transport is predicted to occur every year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given Full Use of the Existing System; a Current Conditions (2006) 10-year flood is predicted to occur every 8 years for this alternative. Effective discharge is predicted to occur approximately every year at this location given Full Use of the Existing System. Overall differences between Current Conditions (2006) and Full Use of the Existing System are considered insignificant and no changes in channel morphology are predicted at this location.

Increased flows resulting from the No Action Alternative are predicted to increase the bedload sediment transport capacity at this location by approximately 24% and sediment supply by 5%. Phase 2 sediment transport is predicted to occur every year with flows above the threshold for Phase 2 transport occurring approximately 55 days per year. Phase 2 transport is predicted to occur every year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 4 years at this site given the No Action Alternative; a Current Conditions (2006) 10-year flood is predicted to occur every 10 years for this alternative. Effective discharge is predicted to occur approximately once every 1.1 years at this location given the No Action Alternative. Overall differences between Current Conditions (2006) and Full Use of the Existing System compared to the No Action Alternative are considered insignificant and no changes in channel morphology are predicted at this location.

Increased flows resulting from the Proposed Action with RFFAs are predicted to result in a decrease in the bedload sediment transport capacity at this location by approximately 17% while sediment supply is predicted to increase by 7%. Phase 2 sediment transport is predicted to occur every year with flows above the threshold for Phase 2 transport occurring approximately 32 days per year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 12 years at this site given the Proposed Action with RFFAs; a Current Conditions (2006) 10-year flood is not predicted to occur within the modeled 45 year period for this alternative. Effective discharge is predicted to occur approximately once every 1.4 years at this location given the Proposed Action with RFFAs. Overall sediment transported by this alternative is predicted to decrease despite flow increases given the planned timing of releases from the reservoir. Reductions in transport and the frequency of flows initiating Phase 2 transport are expected to decrease erosive potential in the stream and potentially reduce the need for localized bank stabilization when compared to Current Conditions (2006).

Increased flows resulting from Alternative 8a with RFFAs are predicted to result in a decrease in the bedload sediment transport capacity at this location by approximately 16% while sediment supply is predicted to increase by 7%. Phase 2 sediment transport is predicted to occur every year with flows above the threshold for Phase 2 transport occurring approximately 32 days per year. The flow categorized as the 5-year flood event based on Current Conditions (2006) hydrology is expected to occur with a recurrence interval of 12 years at this site given Alternative 8a with RFFAs; a Current Conditions (2006) 10-year flood is not predicted to occur within the modeled 45 year period for this alternative. Effective discharge is predicted to occur approximately once every 1.8 years at this location given Alternative 8a with RFFAs. Overall Alternative 8a is predicted to be very similar to the Proposed Action with RFFAs as sediment transported by this alternative is predicted to decrease despite flow increases given the planned timing of releases from the reservoir. Reductions in transport and the frequency of flows initiating Phase 2 transport are expected to decrease erosive potential in the stream and potentially reduce the need for localized bank stabilization when compared to Current Conditions (2006).

Overall Conclusions for the South Boulder Creek Basin

Results generated from the Representative sites on South Boulder Creek were used to predict impacts throughout the stream. Based on the results of this analysis, the stream system appears to be stable from a channel morphology standpoint, although past channel armoring activities indicate past bank erosion. Altered flows resulting from the Project alternatives with RFFAs will increase flows throughout this area. Channel segments both above and below Gross Reservoir are not expected to be impacted in terms of channel morphology for Full Use of the Existing System or the No Action Alternative. Given the Proposed Action and Alternative 8a, it is predicted that increased flows will continue to cause erosive forces that may increase the need for localized bank stabilization when compared to Current Conditions (2006) for stream segments above the reservoir. Operations of the reservoir, which are planned to release less water during peak flow periods, are predicted to decrease erosive potential downstream of the reservoir given the Proposed Action and Alternative 8a with RFFAs.

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4.6.4 Groundwater

The affected environment for groundwater is described for Current Conditions (2006) in Section 3.4, which includes a discussion of additional groundwater data that was collected in the fall 2010 in response to comments received on the Draft Environmental Impact Statement (EIS). This cumulative impacts analysis evaluates the potential effects on groundwater of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to groundwater are evaluated by comparing to Current Conditions (2006). A general discussion of the cumulative effects to groundwater related to changes in stream flows and reservoir elevations (as described in Section 4.6.1) is included in this introduction, followed by a discussion of alternative-specific cumulative effects.

Groundwater and Surface Water Interactions

Changes to surface stream flow rates may affect groundwater because of stream-aquifer interactions within the natural hydrologic system. Surface water and groundwater are linked components of the hydrologic system in every watershed. Snowmelt infiltration recharges the groundwater flow system in each potentially affected watershed. Snowmelt also causes runoff during the spring and early summer months which increases stream flows. Depending on the elevation of water levels in streams compared to the adjacent groundwater levels, water flows between surface water bodies, streams, and aquifers. Thus, changes in surface water levels may also affect groundwater levels.

Recharge to groundwater is a dynamic hydrologic process involving the deep infiltration of water derived from precipitation. In upland areas of a watershed, snowmelt and rainfall infiltrates the shallow surface soils and migrates below the root zone down to the water table. After reaching the water table, groundwater migrates away from higher water table elevations and toward the lower elevation areas of the watershed. In some areas, recharge is also contributed by water seepage beneath lakes and streambeds in the upland portions of the watersheds. In the lower elevation areas of a watershed, typically along stream courses, groundwater levels may rise above ground surface creating springs or causing seepage into streams or lakes. Thus, groundwater resources may be impacted by projects that change the physical characteristics of the land surface affecting recharge rates, or change the levels of surface water bodies or stream flows.

General Cumulative Effects to Groundwater Due to Changing Stream Flows

The potential cumulative impacts to groundwater resources due to changes in stream flows would be none to minor. Any effects would be limited to the areas immediately adjacent to streams and would only occur during wet and average runoff years, not during dry years. Estimates of the increase or decrease in stream flows for the Moffat Project and other RFFAs were based on the Platte and Colorado Simulation Model (PACSM) predictions of stream flow changes as described Section 4.6.1. Durations and relative magnitudes of predicted stream flow changes provide indications of potential Project and cumulative effects on groundwater in the immediate vicinity of the stream segments. However, Project-related and cumulative changes in elevation of the stream levels more directly influence the groundwater levels and flow interactions along the streams. Thus additional hydraulic modeling of the stream levels was performed using the Hydrologic Engineering Centers-River Analysis System (HEC-RAS) model as described in Section 4.6.8.

Potential impacts to groundwater expected for the Proposed Action with RFFAs are described for average year conditions because those effects would be larger than in wet years. The Moffat Project would not remove additional water from these streams during dry years. Thus, the Project with RFFAs would not change the low flow, dry year hydrologic conditions. The HEC-RAS hydraulic modeling relies on field data for each Representative reach and PACSM stream flow predictions.

As described in Section 3.4, groundwater generally flows toward and discharges into the streams within the watersheds in the Project area. Along some potentially affected stream segments, the changes in stream levels would affect the hydraulic gradient[4] between the groundwater and the stream. A drop in stream level would cause a similar drop in the groundwater level immediately adjacent to the stream, which could slightly increase groundwater flow toward and into the stream. On the other hand, if any stream segments currently lose water to groundwater, a lower stream level would cause the seepage rate through the streambed to decrease.

Any decrease in streambed seepage would be much smaller than the amount of decrease in stream flow because the rate of seepage is controlled largely by the hydraulic conductance of the stream bed. Hydraulic conductivity is primarily a function of the physical properties of the streambed, sediment thickness, porosity and grain-size distribution. The other important factor affecting streambed seepage rate is the hydraulic gradient between the stream level and the groundwater level beneath the streambed. Large changes in stream flow are accompanied by relatively small changes in stream level elevations, especially in mountain watersheds with large topographic relief. Thus, relatively small changes in hydraulic gradients along potentially affected stream segments in the Project area are anticipated.

The Moffat Project with RFFAs would not change any of the locations or physical features of the existing Board of Water Commissioners' (Denver Water's) diversion structures located west of the Continental Divide. Rather, Denver Water is proposing to obtain the additional water from the West Slope watersheds by extending the duration of the stream flow diversions at existing diversion structures during peak runoff periods in wet and average years. Downstream of the Denver Water's diversion structures there is a slight potential for localized groundwater impacts due to changes in stream flows and levels. The areas and degree of these potential cumulative effects are further described below.

[4]The hydraulic gradient is defined by the difference in hydraulic head, divided by the distance between two points along a groundwater flow path. For example, where the groundwater hydraulic gradient is toward the stream, groundwater will flow toward the stream. Similarly, an upward hydraulic gradient causes upward groundwater flow.

General Cumulative Effects to Groundwater Due to Changing Reservoir Levels

Each of the Moffat Project alternatives with RFFAs involve transferring additional water diverted from the Fraser River and Williams Fork River on the West Slope, through the Moffat Tunnel and down South Boulder Creek on the East Slope. Except for the additional water diverted into the South Platte River from Dillon Reservoir, which is located in the Blue River watershed, the additional water obtained from the West Slope watersheds would be stored in reservoirs on the East Slope, or sent to meet customer demand. Increases in reservoir water level elevations would increase seepage rates from reservoirs and cause groundwater levels to rise in adjacent areas. Increases in groundwater levels may also increase groundwater flow rates to springs and streams near reservoirs, which under some circumstances could affect groundwater quality, and existing wetlands nearby. For this EIS, the assessment of potential groundwater impacts relied on the surface water hydrology analysis described in Section 4.6.1 as well as other available hydrogeologic information.

Overall, the long-term cumulative changes in reservoir levels described in Section 4.6.1 would be too small to cause discernable cumulative effects on groundwater resources at any of the West Slope reservoirs in the Project area. On the East Slope however, raising the dam at Gross Reservoir may create minor cumulative effects on groundwater levels near the reservoir. Alternative 1c includes the development of a new Leyden Gulch Reservoir, which would be located along the South Boulder Diversion Canal. The construction and utilization of this new reservoir may cumulatively affect groundwater quality.

4.6.4.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Reservoirs

As described in Section 4.6.1.1, the expected water level changes in reservoirs would be relatively small compared to the historical ranges for each of the potentially affected reservoirs on the West Slope. On the East Slope however, the water level in Gross Reservoir would rise substantially because the dam height would be raised as part of the Proposed Action with RFFAs. The projected normal high water level would be 124 feet higher than for Current Conditions (2006).

The increased storage proposed for Gross Reservoir to accommodate the additional water diverted from the Fraser River and the Williams Fork River would likely cause increased seepage from the reservoir to the groundwater system. The higher reservoir level would cause a rise in groundwater levels adjacent to the reservoir. In areas upstream of the reservoir, this groundwater mounding effect would cause the eastward hydraulic gradients to decrease and thus reduce the eastward rate of groundwater flow toward the reservoir. Wetlands that currently exist along the edge of the reservoir would be inundated with water under the new storage scenario. However, new wetlands are likely to form in upstream fingers of the expanded reservoir, which would be sustained by shallow groundwater, similar to Current Conditions (2006).

Downstream of Gross Reservoir, the additional water flows diverted during the peak runoff periods in wet and average years would cause the baseflow component of South Boulder

Creek to increase slightly because of increased groundwater levels and seepage from the reservoir. During the low flow season of these years, the higher reservoir seepage rates would provide more groundwater discharge in the creek.

Other than raising Gross Dam, there would be no discernable cumulative effects on groundwater resources to reservoirs in the Project area under the Proposed Action with RFFAs.

River Segments

West Slope

Past water-related actions on the West Slope, including impoundments, diversions, and inter-basin transfers, have affected stream flows which may have had an effect on groundwater levels downstream of Denver Water diversions. Stream flow reductions have likely diminished the extent and duration of flooding along stream channels and backwaters, and reduced the extent of overbank flooding. More recently, irrigated land area increases have affected the runoff rates and availability of surface water. Population increases on the West Slope, particularly after about 1970, have also increased groundwater use. Even though additional water rights are no longer available to allow further withdrawal of tributary groundwater, it will continue to be possible for new residents to install small-capacity wells to supply individual cabins because such wells are exempt from permitting by the State Engineers' Office (SEO).

Under the Proposed Action with RFFAs, stream flows are predicted to decrease during the seasonal high runoff period. The maximum reductions in peak flow would be along the Blue River and the Fraser River, typically in June or July. Changes in the level of the rivers would cause localized, minor effects on the groundwater levels and only in the area immediately adjacent to the rivers. Groundwater levels would decrease slightly, and the hydraulic gradient in groundwater near the river would increase slightly, in response to the reductions in seasonal high stream flows. Estimates of groundwater level changes along the river segments are provided at the end of this section and are based on stream flow hydraulic modeling and available hydrogeologic information. First however, it is important to clarify what areas within the West Slope watersheds could potentially be affected by the Moffat Project with RFFAs.

Groundwater conditions in the Fraser River Valley are described first because there are more hydrogeologic and stream flow data available in this valley, and also because the total environmental effects would likely be larger here than for the other mountain watersheds in the Project area. The Moffat Project in conjunction with other RFFAs, including pumping of alluvial groundwater for agricultural and domestic use, would not change groundwater recharge rates within the blue and brown areas delineated on Figure 3.4-1, a map of the Fraser River watershed. Groundwater recharge rates would remain the same as Current Conditions. This is true not only for Fraser Valley watershed but is also the case in high-elevation areas of the other mountain watersheds. Upstream of the Denver Water diversion points, the uplands and areas along the stream channels in the blue areas would not be affected by the Moffat Project with RFFAs. As for the blue area, both the uplands and the tributary channels in the brown area are upstream of any Denver Water diversion points.

The blue and brown areas of Figure 3.4-1 include the highest land surface elevations, precipitation rates, and snowpack amounts. Precipitation and snowmelt infiltrate though permeable soils and fractured rocks in the upland areas to become groundwater recharge. Thus, groundwater recharge occurs naturally throughout the blue and brown areas on Figure 3.4-1. Groundwater generally flows downhill away from the higher elevation recharge areas and toward discharge areas along the streams lower in the valley.

Unaffected stream channel segments are depicted with light blue lines on this watershed map. Along those stream segments, groundwater recharge contributed by seepage through the bottom of stream beds would not change due to the Project with RFFAs at any time of year because those stream beds are not downstream of any Denver Water diversions. Therefore, the Proposed Action with RFFAs would not impact groundwater recharge rates, groundwater flow directions, flow rates, or the water available to wells in any of those areas.

The white area of Figure 3.4-1 is another area in which groundwater recharge rates would not change because this land is outside the limits of the potentially-affected stream segments. Thus, the white area is not downstream of any Denver Water diversion points. As is true for the blue and brown areas on Figure 3.4-1, none of the hydrogeologic factors controlling water infiltration and groundwater recharge rates would change within the white area as a result of the Project with RFFAs.

Seepage rates beneath stream segments directly downstream of the Denver Water diversion points in the Fraser Valley could possibly decline because of the Proposed Action in conjunction with other RFFAs. However, this could only occur in areas directly beneath the affected stream segments, which are shown as golden brown lines on Figure 3.4-1. Streambed seepage rates would decline only if the stream levels are higher than the ambient groundwater levels during the proposed diversions. However this situation has not been found in Fraser Valley where definitive data were collected by the Corps in fall 2010 and summer 2011.

To further evaluate the groundwater-stream interactions in the Project area, additional groundwater data were collected at four study sites along several potentially-affected stream segments in the Fraser Valley, as described in Section 3.4.5.1. Locations of these groundwater study sites are shown on Figure 3.4-2. Monitoring data collected during the low flow season (October 2010) and the high flow season (June-July 2011) show groundwater levels are higher than the adjacent stream levels, and groundwater hydraulic gradients converge toward the streams. Thus, these data indicate groundwater flows toward and into the streams during the seasonal low flow period as well as during the peak runoff period.

Together with the other hydrogeologic information provided in Section 3.4.5.1, these site-specific groundwater monitoring data indicate that infiltration of precipitation and snowmelt causes groundwater recharge throughout the watershed. Recharge in the upland areas causes groundwater to flow away from uplands, and toward the stream valleys and lower-elevation portions of the watershed. Along the streams, groundwater discharges from ground surface at seeps and springs, and contributes to stream flows. In those areas, groundwater is consumed by phreatophyte vegetation in riparian and wetland areas. Wetlands that occur more than a few feet above the seasonal high stream level are supported primarily by the groundwater recharged by snowmelt infiltrating below the adjacent upland areas, not along the stream valleys.

Under Current Conditions (2006), the Moffat Collection System stream diversions reduce the flows in some West Slope tributaries to zero cfs immediately downstream of the diversion structures. Further downstream of the diversion points, flows return to these tributaries. The lengths of these dry streambeds change month-to-month and year-to-year because of annual variations in local snowpack amounts and air temperatures during the snowmelt period, which would also be true in the future. Seepage beneath the unlined diversion structures (e.g., canals and reservoirs) occurs under Current Conditions (2006) at all times when there is water in those structures.

In assessing potential cumulative effects of the diversions, available academic research was also considered. For a master's thesis, streams in the Fraser River watershed were studied to evaluate aquatic habitat and recovery downstream of the existing Denver Water's diversion structures (McCarthy 2008). This thesis indicated there were minimum bypass flows at 11 of the 29 diversion structures in June 2006. The remaining 18 diversion structures were removing nearly all of the stream flow. At 9 of these 18 locations, flow recovered downstream of the diversion structures. At the 9 diversions in which stream flows recovered downstream, McCarthy (2008) states: "Downstream of diversion structures, flow recovery was evident at all sampled reaches via groundwater recharge within 0.41 kilometer or less of the diversion structure. This influx to the stream reaches is most likely the resurfacing of shallow groundwater or hyporheic flows from the impounded area upstream of the diversion structure. However, influx to the stream reaches could also be contributed from saturated topsoil, deeper groundwater seepage points, or alluvial valley bottom storage."

McCarthy (2008) also notes that in some areas below the diversions, tributaries and wetlands contribute more water to stream flow than groundwater. McCarthy states: "It is also important to note that these results reflect a subset of streams that are able to maintain discharge from initial recovery point to confluence with a larger stream. In the summer of 2006, nine of the streams in the Fraser River Basin that were 100 percent (%) diverted showed no recovery and either consisted of a series of unconnected pools or were completely dry along the entire channel to the confluence."

Observations from McCarthy (2008) add to, but do not conflict with, the detailed descriptions of groundwater conditions in Section 3.4. Denver Water diversions cause some stream segments to have decreased flow and even go dry at some locations under Current Conditions (2006). The additional stream water diversions proposed for the Moffat Project with RFFAs would likely cause the dry reaches of those tributaries to extend a short distance further downstream, and would prolong the duration of these dry sections during average years. However, in many of these stream segments, the influx of groundwater or tributary water further downstream would contribute to stream flow recovery. Reductions in stream flow attributable to the Moffat Project with RFFAs would be partly offset by groundwater influx to the streams.

Groundwater data and other hydrogeologic information presented in Section 3.4, together with the stream flow modeling described in Section 4.6.1 and Section 4.6.8, indicates there will be, at most, negligible cumulative changes in groundwater recharge directly beneath potentially-affected stream segments. Currently available information does not indicate there are any areas where stream levels are higher than groundwater levels next to the potentially affected stream segments. Nonetheless, it is possible that situation does exist along some stream segments and the Moffat Project with RFFAs could reduce the rate of streambed seepage into groundwater during some periods. If so, then the seepage rates would remain very similar to Current Conditions because: (1) the high-flow stream levels and wetted areas of the channels would only change by a very small amount, (2) groundwater flows generally toward and into the streams throughout the watershed, and (3) the hydraulic conductance of the streambed materials would not be cumulatively affected by the Proposed Action and RFFAs.

At most, the streambed seepage rates along potentially affected stream segments would cumulatively decrease by an exceedingly small amount. The timing of the Proposed Action with RFFA diversions would coincide with high runoff periods in wet or average years. Appendix H-9 provides a series of flow duration curves based on PACSM results for a number of locations along the Fraser River and tributaries downstream of the diversion points. Those curves indicate that the potential cumulative changes in flow durations attributable to the Project with RFFAs would occur only when there are higher flow rates, which typically correspond with the snowmelt runoff season.

Hydraulic modeling using the HEC-RAS model was conducted to analyze the changes in stream levels and peak flow inundation areas, at Representative sites downstream of the Denver Water diversion points in combination with other RFFAs. For impact assessment of wetland and riparian areas, Section 4.6.8 provides additional information regarding stream level changes and inundated areas.

Changes in stream flood levels were modeled using the Corps HEC-RAS computer software (version 4.0) for analysis of stream hydraulics. This analysis is presented in the Moffat Collection System Project Existing Channel Conditions Report (ERC 2006), a summary of which is provided in Section 4.6.8. The HEC-RAS hydraulic models were used in conjunction with the PACSM results to generate water surface-profiles for each reach. For each Representative reach, the HEC-RAS modeled was simulated for the 1.5-, 2-, 5-, and 10-year flood events for each EIS scenario (Current Conditions, Full Use of the Existing System, No Action Alternative, and the action alternatives). Probability plotting was used to estimate the flood flow rates for the recurrence intervals evaluated, and a summary of those results is provided in Table 4.6.8-1. Model predicted changes in flood elevations and widths are shown in Tables 4.6.8-2, 4.6.83, and 4.6.8-4 (refer to Section 4.6.8).

These hydraulic model predictions indicate the 2-year peak flows would decrease in the Fraser River, Colorado River and Blue River. Of all these sites, Site BR1 on the Blue River would have the largest stream level reduction during the high runoff season, about 14 inches, which would reduce the stream width by about 10 feet. The next largest change would be at Site FR1 on the Fraser River near Winter Park, where the peak stream level would be lowered by about 9 inches during the model-predicted 2-year flow event. At that point, the wetted channel width would decrease by about 4 feet. At other sites along the potentially affected West Slope stream segments, the reduction in peak stream level would be even smaller, less than about 4 inches. Potentially affected stream segments on the East

Slope would have negligible cumulative increases in peak stream level and width, except for Site SBC3 on South Boulder Creek which would have a small decrease, about 2 inches.

For larger, less frequent seasonal peak stream flows, the predicted changes are even smaller than for the 2-year peak flows. Tables 4.6.8-2 through 4.6.8-4 show the predicted stream level changes for 5- and 10-year recurrence interval flows. During a 5-year peak flow, the largest cumulative change in stream level would be along the Blue River at Site BR1, a decline of about 7 inches. The site with the next largest change is Site FR1, at which the predicted change in stream level would be about 4 inches during a 5-year peak flow event. The predicted change stream widths at both these sites would be about 4 feet during peak flow. For the 10-year peak flow event, Table 4.6.8-3 shows that the model predicted changes in stream levels and widths would be even smaller than for the 5-year flow.

Changes in peak stream levels would cause similar amounts of groundwater level changes in the shallow aquifer immediately adjacent to the streams during the seasonal high runoff period. However, these changes would not be large enough to change the overall groundwater flow pattern within the affected watersheds. Groundwater would continue to flow from upland areas toward and into the principal streams. Also the small magnitude of the expected groundwater level changes during the peak runoff season would not reduce the availability of flow of groundwater to wells located near the streams.

Considering the available information provided above, there would be minimal cumulative impacts to groundwater resources due to changes in stream flow. In wet and average years, the Proposed Action in combination with other RFFAs, would not impact groundwater levels except downstream of Denver Water diversion points west of the Continental Divide, in areas immediately adjacent to those stream segments. Declining stream levels attributable to the Proposed Action with RFFAs would likely cause very minor short-term cumulative reductions in groundwater levels next to the streams and minimal decreases in streambed seepage rates. During snowmelt runoff, local recharge contributed by streambed seepage may be temporarily reduced by the proposed diversions in some reaches, but only very slightly. Groundwater recharge rates would not change substantially during wet and average years for any of the watersheds. During dry years, there would be no additional water diversions by Denver Water.

East Slope

As previously discussed, historical development and groundwater use on the West Slope has likely caused slight groundwater level declines and groundwater quality degradation in some relatively populated areas, but these effects are likely much smaller than the effects of population growth and water use on the streams. On the East Slope, however, the Denver Water diversions into streams have likely caused slight increases in groundwater levels along those streams. Groundwater levels would rise slightly near the banks of these rivers, as stream flows rise, but within the range of normal seasonal fluctuations. The surface water diverted into these streams will be of very high quality, which would not impact groundwater.

Groundwater Quality

Cumulative impacts related to groundwater quality changes are not expected to be substantial. There are currently Wastewater Treatment Plant (WWTP) discharges to the

Blue River at a point just below Dillon Reservoir, and into the Fraser River at Winter Park and at Fraser. Stream flow reductions could reduce the capacity of the river to assimilate these WWTP discharges. However, this effect would be relatively minor during the peak runoff period. If the quality of the stream water downstream of the WWTP effluent discharge point is degraded, this could conceivably impact groundwater quality if the affected stream water seeps into groundwater. However, there are no known potentially affected stream segments along which there would be stream bed seepage into groundwater. Thus, it is unlikely that groundwater quality would be cumulatively affected by the Proposed Action in combination with other RFFAs.

4.6.4.2 Alternative 1c with Reasonably Foreseeable Future Actions

Reservoirs

The expansion of Gross Reservoir under Alternative 1c would cause similar, but smaller, impacts than the Proposed Action with RFFAs due to the smaller expansion (40,700 acre-feet [AF]). Similarly, reservoir seepage would be less and the change in hydraulic gradients around the reservoir would be less under Alternative 1c.

Groundwater effects related to seepage and changes in hydraulic gradients due to the development of a new Leyden Gulch Reservoir site along the South Boulder Diversion Canal would be, in general, similar to those described for the expansion of Gross Reservoir. Those effects would include raising the groundwater levels beneath and along the perimeter of the reservoir. In the Leyden Gulch area, as in the Gross Reservoir Expansion area, rising groundwater levels would not create an adverse environmental impact. There are no other RFFAs that, in combination with Alternative 1c, could adversely impact groundwater in the Leyden Gulch area. However, past land uses in that vicinity should be considered such as the former Rocky Flats facility discussed below.

The southern boundary of the U.S. Department of Energy Rocky Flats site is near the proposed Leyden Gulch Reservoir site. As described in Section 5.20, soil and groundwater at Rocky Flats has been extensively analyzed for radioactive isotopes and other contaminants. Remediation has also been conducted at Rocky Flats to address the risks posed by the contaminated soils found at the plant. Site closure was completed in 2006. During construction of a new reservoir, it is possible but unlikely that unknown contaminants could be remobilized from soil to groundwater. The increased recharge to groundwater from the proposed reservoir and influence of construction activities may increase the rate of contaminant mobility. However, natural recharge of the groundwater system from infiltration of precipitation is already occurring at the site. Additionally, seepage of good quality water out of the reservoir would provide natural attenuation by dilution. For example, the natural flushing action would reduce the content of salts in soils in which evapo-concentration of constituents in precipitation and rocks have naturally affected the surface soils within the proposed reservoir area.

River Segments

The sources for additional water supply under Alternative 1c are the same as those described above for the Proposed Action with RFFAs. The cumulative impacts to groundwater resources would be the same as those described above in Section 4.6.4.1.

4.6.4.3 Alternative 8a with Reasonably Foreseeable Future Actions

Reservoirs

The predicted changes in the water levels in the West Slope reservoirs and the effects of expanding Gross Reservoir under Alternative 8a would cause similar, but smaller, impacts to groundwater as those due to the Proposed Action with RFFAs. Compared to the Proposed Action with RFFAs, the smaller Gross Reservoir enlargement (52,000 AF) proposed in Alternative 8a would cause a smaller rate of seepage from the reservoir and smaller changes in the groundwater levels near the reservoir.

South Platte River Facilities

Alternative 8a involves diversion of water from the South Platte River (reusable river return flows and reusable effluent). The diverted water would be stored in gravel pits near the river. Even in combination with the effects of past, present, or other reasonably foreseeable water-related actions, the removal of water from the South Platte River under Alternative 8a would not substantially change groundwater levels near the river. The amount of reusable return flows extracted from the river for this alternative would cause an immeasurable drop in river volume and level (i.e., less than 1% of the total river flow) during the high flow season. During the low flow time of the year, the removal of additional water from the South Platte River under Alternative 8a would slightly decrease the surface water elevation of the river, which would slightly reduce the groundwater elevations near the river. Groundwater quality would also not be affected by such small changes in the river flow.

By design and regulation, the gravel pits used for storage of the additional water removed from the South Platte River would be surrounded by a slurry wall to restrict seepage from the storage pit to the groundwater system. The slurry walls would be keyed into the Pierre Shale, which underlies the alluvial aquifer in that area. While the Pierre Shale is known to contain naturally-elevated levels of selenium in some other areas, construction and operation of the South Platte River Facilities are not expected to cause impacts to groundwater quality. Mobilization and transport of selenium from the Pierre Shale is unlikely to be significant in areas where the Pierre Shale has been exposed to stream erosion and weathering processes for thousands of years. Thus, natural flushing of selenium from the weathered shale by alluvial groundwater flow has likely reduced selenium levels at the proposed location of the gravel pits. Moreover, the extremely low permeability of the slurry walls and the Pierre Shale would restrict seepage out of the gravel pit storage areas and thus preclude any adverse cumulative impacts to groundwater levels and groundwater quality in the area of the gravel pits.

The conveyance of water in Conduit O and the gravel pits pipeline would not affect the groundwater resources because the water would be enclosed within pipelines or lined canals. Even if there were a total failure of the conveyance network, the water released would be of good quality and thus would cause negligible cumulative impacts to groundwater resources.

River Segments

The sources for additional water supply included under Alternative 8a are the same as those described for the Proposed Action with RFFAs. Most of the additional surface water diversion would be collected in the upper reaches of the West Slope watersheds in the Fraser and Williams Fork river basins. The total environmental effects to groundwater resources of diversions from the West Slope are described in Section 4.6.4.1. However, a portion of the water supply for Alternative 8a would be from reusable water in the South Platte River. As a result, diversions from the West Slope basins would be slightly less than those described for the Proposed Action with RFFAs, and thus would cause smaller cumulative effects to groundwater than those described in Section 4.6.4.1.

4.6.4.4 Alternative 10a with Reasonably Foreseeable Future Actions

Reservoirs

The predicted changes in the water levels in the West Slope reservoirs and the effects of expanding Gross Reservoir under Alternative 10a would cause the same impacts as described for Alternative 8a with RFFAs in Section 4.6.4.3.

Denver Basin Aquifer Facilities

Alternative 10a proposes to use the Denver Basin aquifers for storage and recovery of reusable return flows. Three injection and recovery wells would be installed at each well site, in the upper Arapahoe, lower Arapahoe, and Laramie-Fox Hills aquifers, with approximately 24 locations throughout the Denver Metropolitan area. The reusable water would be treated at a new Advanced Water Treatment Plant (AWTP) prior to injection into the Denver Basin aquifers. The treated water must meet all established groundwater quality standards so the injected water would not degrade the existing groundwater quality. In addition, the injected water should be tested to establish compatibility with the aquifer water and aquifer host rock. If certain chemical characteristics of the injected water vary in quality from those in the aquifer, such as the oxidation-reduction potential of the water, naturally-occurring metals could be mobilized from the aquifer host rock. However, Denver Water would employ water treatment measures to preclude any such water quality impact to the recovered water or the native groundwater in the aquifers.

Water levels in existing water wells in the vicinity of the proposed Denver Water injection and recovery wells would fluctuate in response to injection and withdrawal pumping. However, such pumping impacts would diminish exponentially with distance away from the Denver Water wells.

Through the SEO permitting process, the distance between these injection and recovery wells and other water well users would be greater than 600 feet (CDWR 2008a, 2008b). This permit-required separation distance would protect other water well users from groundwater level fluctuations that could otherwise be detrimental to existing water wells and current users if separation distances were smaller.

In assessing the total environmental effects of this alternative, it was also important consider past, present, and other RFFAs in the Denver Metropolitan area. Declining groundwater levels have occurred and are continuing in the deep aquifers throughout the Denver area where Denver Water has identified 24 potential well locations. Most of the groundwater level decline has occurred since the 1950s, and continues at an unsustainable rate in some areas. In other Denver Basin areas, however, groundwater level declines appear to have stabilized. Overall, the net long-term cumulative impacts on groundwater levels due to the proposed Denver Water wells would be minimal because Denver Water intends to only recover the amount of water injected into aquifer storage.

Nonetheless it is unlikely that the water injected would be completely removed during the following withdrawal cycle. Rather a component of the water volume pumped during the withdrawal cycle would be natural groundwater from these deep aquifers. Thus, a component of the treated water injected into the aquifer would remain in the aquifer after the withdrawal cycle. With time, this could change the water quality within the aquifers throughout the area in which the 24 Denver Water injection/withdrawal wells would operate. To minimize the potential adverse impact on these aquifers, it would be essential to inject water of excellent water quality, not only water meeting drinking water standards, but also water consisting of geochemical properties that would not react with the aquifer rocks causing the release of toxic constituents into the groundwater.

The potential cumulative impacts on the groundwater system due to conveyance of water in Conduit M are similar to those described for Conduit O under Alternative 8a.

River Segments

The sources for additional water supply included under Alternative 10a are the same as those described for the Proposed Action with RFFAs. Additional surface water would be diverted from the existing Denver Water Collection System in the upper reaches of the West Slope watersheds. Thus, the cumulative effects on groundwater resources on the potentially affected stream segments are expected to be the same as those described in Section 4.6.4.1.

4.6.4.5 Alternative 13a with Reasonably Foreseeable Future Actions

Reservoirs

The predicted changes in the water levels in the West Slope reservoirs and the effects of expanding Gross Reservoir under Alternative 13a would cause similar, but smaller, groundwater effects as those for the Proposed Action with RFFAs due to the smaller expansion (60,000 AF). The potential impacts on the groundwater resources due to the conveyance of water in Conduit O for Alternative 13a would be the same as those described for Alternative 8a in Section 4.6.4.3.

South Platte River Facilities

Potential cumulative effects on groundwater caused by the South Platte River Facilities under Alternative 13a would be similar to those described for Alternative 8a. This alternative, however, also includes the conversion of agricultural water rights to municipal or other non-irrigation uses. Therefore, less groundwater recharge would occur in localized areas that are no longer irrigated. Reducing the amount of irrigation water may cause minor cumulative declines of the water table in these areas.

River Segments

The sources for additional water supply included under Alternative 13a are the same as those described for the Proposed Action with RFFAs. Most of this additional surface water diversion would be collected in the upper reaches of the West Slope watersheds in the Fraser and Williams Fork river basins. The total environmental effects on groundwater resources potentially caused by these increased diversions are described in Section 4.6.4.1. However, a portion of the water supply for Alternative 13a would be from newly purchased agricultural water rights in the South Platte River and from the Blue River, South Platte River, and South Boulder Creek. As a result, diversions from the West Slope basins would be slightly less than and thus would cause smaller cumulative effects to groundwater than the Proposed Action with RFFAs.

4.6.4.6 No Action Alternative with Reasonably Foreseeable Future Actions

There are no ground-disturbing activities associated with the No Action Alternative. The predicted future water demands would be met using current infrastructure and by withdrawing more stream runoff from the Denver Water diversion points on the West Slope up to the legal limit of Denver Water's water rights.

The cumulative effects of the No Action Alternative on groundwater would be similar to, but probably somewhat greater than, those described for the Proposed Action with RFFAs for the West Slope watersheds. Downstream of the existing diversion structures, the creeks would be narrower and shallower over a longer period of time in the fall due to the continual withdrawal of water to meet higher demands throughout the year.

The width and depth of streams would vary annually depending on the rate of Denver Water diversions, as well as the amount of snowpack and summer precipitation. Groundwater levels near the streams would change by similar amounts as the stream levels. Compared to the Proposed Action with RFFAs, groundwater levels would have larger changes seasonally because Denver Water would be diverting water year round, as needed, not just during the high runoff season. Outside the areas immediately alongside the affected stream segments, the No Action Alternative would cause the same effects as the Proposed Action with RFFAs on groundwater levels and groundwater recharge rates.

On the East Slope, the Moffat Collection System components would remain the same as those currently in use. However, due to the higher future demands and without additional water storage capacity, the No Action Alternative would cause water levels in the reservoirs to generally be lower than the Proposed Action with RFFAs. More frequent low reservoir levels would decrease the seepage from the reservoirs into groundwater. This would likely cause groundwater levels to decline over the long term near the reservoirs.

No additional impacts on groundwater would result from implementing the Combination Strategy. Changes in stream flow between the two No Action Alternative strategies are expected to be minimal. In summary, the total environmental effects under the No Action Alternative on groundwater resources would be similar to but somewhat greater than those described for the Proposed Action with RFFAs.

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4.6.5 Geology

Land development in the Project area may utilize geologic resources for construction activities or expose geologic hazards. Geologic resources covered by or used in the construction of buildings, pavement, or other aboveground facilities are considered permanently lost.

The affected environment for geology is described for Current Conditions (2006) in Section 3.5. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential effects to geology are evaluated against Current Conditions (2006).

4.6.5.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Past regional population growth and development in the Front Range has mostly occurred east of the foothills, but has had some effect on the Gross Reservoir area. In addition to areas around the existing Gross Reservoir, the principal developments that have occurred are large-acre residential areas, roads, and a railroad. No new or proposed residential development is projected in the area and private development opportunities are limited since the reservoir is primarily surrounded by U.S. Forest Service (USFS) land and Boulder County Open Space. The Proposed Action with RFFAs would contribute to the removal and use of sand and gravel deposits for dam construction at Gross Reservoir. Additionally, there may be a loss of unmined sand and gravel deposits due to reservoir inundation. Other current and projected land development activities would result in demands for sand and gravel resources in the general area, creating a minor cumulative impact to geological resources.

Geological hazards associated with the Moffat Project with RFFAs would be addressed in design and monitored during construction activities, as described in Section 5.5.7. Other proposed land development activities within the Project area would also implement appropriate design and mitigation measures. Thus, it is anticipated that current and projected land development activities would result in minor cumulative impacts to potential geologic hazards.

4.6.5.2 Alternative 1c with Reasonably Foreseeable Future Actions

The total environmental effects to geologic resources at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (40,700 acre-feet [AF]).

The total environmental effects to geologic resources at Leyden Gulch Reservoir would rely on mined material from the reservoir pool area and therefore would not contribute to the removal and use of sand and gravel deposits from the general vicinity. Current and projected land development activities and transportation improvements would result in demands for sand and gravel resources in the general area, creating a minor cumulative impact to geological resources.

4.6.5.3 Alternative 8a with Reasonably Foreseeable Future Actions

The total environmental effects to geologic resources at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (52,000 AF).

It is assumed that all economically viable sand and gravel deposits associated with the South Platte River gravel pits would be independently mined prior to acquisition of the facilities by the Board of Water Commissioners (Denver Water). Since Conduit O would be constructed in previously disturbed roads and other right-of-ways (ROWs), geologic resources would not be affected. Proposed development within the Project area would likely occur outside of alluvial areas where sand and gravel deposits are present, but would require use of sand and gravel from various sources for construction. Regardless of whether the Moffat Project with RFFAs are implemented, it is not anticipated that the availability of sand and gravel would be adversely affected by cumulative demand.

4.6.5.4 Alternative 10a with Reasonably Foreseeable Future Actions

The total environmental effects to geologic resources at Gross Reservoir would be the same as those described for Alternative 8a.

Since Conduit M, Denver Basin Aquifer distribution pipeline and associated treatment facilities would be constructed in previously disturbed industrial and urban areas including roads and other ROWs. Therefore, geologic resources would not be cumulatively affected.

4.6.5.5 Alternative 13a with Reasonably Foreseeable Future Actions

The total environmental effects to geologic resources at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (60,000 AF).

The total environmental effects to geologic resources for the South Platte River Facilities are the same as those described above for Alternative 8a.

4.6.5.6 No Action Alternative with Reasonably Foreseeable Future Actions

Since no ground disturbing activities would occur under the No Action Alternative, geologic resources would not be cumulatively affected.

4.6.6 Soils

The affected environment for soils is described for Current Conditions (2006) in Section 3.6. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential effects to soils are evaluated against Current Conditions (2006).

Land development unavoidably involves disturbance to soils during construction. Short- and long-term impacts to soils include excavation, removal, erosion, mixing or inversion of soil layers, compaction, and covering by buildings or pavement. Soils covered by buildings, pavement, or other aboveground facilities are considered permanently lost. Soils disturbance is associated with all of the Moffat Project action alternatives.

4.6.6.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Past regional population growth and development in the Front Range has mostly occurred east of the foothills, but has had some effect on the Gross Reservoir area. In addition to areas around the existing Gross Reservoir, the principal developments that have occurred are large-acre residential areas, roads, and a railroad. No new or proposed residential development is projected in the area and private development opportunities are limited since the reservoir is primarily surrounded by U.S. Forest Service (USFS) land and Boulder County Open Space. Additionally, the Gross Reservoir study area is within the Winiger Ridge project area, a partnership of various governmental and private parties, including the USFS and the Board of Water Commissioners (Denver Water), working collaboratively to reduce the potential for catastrophic disease, insect and wildfire incidents. The Winiger Ridge project area includes the land between Boulder Canyon and Coal Creek Canyon, and has a high fuel level for forest fires and an interspersion of wild lands and human population. Actions have included prescribed burns, noxious weed control, forest thinning, fuelbreaks, pine beetle control, and defensible spaces around homes. The USFS has implemented past vegetation treatment west of Gross Reservoir as part of the Winiger Ridge Project. The USFS is currently developing a proposal for future fuels treatment for the Forsythe Fuels Treatment Project, which consists of burning, thinning or a combination of the two management practices. The Forsythe Fuels Treatment Project, if approved, would be implemented in the summer of 2012, and thus would not overlap with construction activities at Gross Reservoir associated with the Moffat Project (Len 2011). The U.S. Army Corps of Engineers' assumption is that since the USFS is the lead regulatory agency for the Forsythe Fuels Treatment Project, they will ensure appropriate measures are in place to minimize soil erosion.

Expansion of the dam, reservoir and related facilities would permanently affect approximately 465 acres of soils. These impacts are described in detail in Section 5.6. Impacts to soils under the Proposed Action with RFFAs would be minimized during construction by implementing Best Management Practices (BMPs) and complying with stormwater management and fugitive dust control plans, as described in Section 5.6.7. Soils disturbance associated with projected development in the Project area would generally be confined to the individual construction areas. Erosion should be limited in these areas by State requirements for stormwater and air quality control plans. Overall, minimal cumulative effects to soils are anticipated within the Gross Reservoir study area.

4.6.6.2 Alternative 1c with Reasonably Foreseeable Future Actions

The total environmental effects to soils at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (40,700 acre-feet [AF]).

Development of the Leyden Gulch Reservoir site would permanently affect 389 acres of soils, as described in Section 5.6. Moderate to high cumulative effects to soils are anticipated in the vicinity of the Leyden Gulch Reservoir site due to possible transportation improvements and the future industrial/office redevelopment at the intersection of State Highway (SH) 72 and SH 93; this redevelopment area is located within 5 miles of the Leyden Gulch Reservoir site.

4.6.6.3 Alternative 8a with Reasonably Foreseeable Future Actions

The total environmental effects to soils at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (52,000 AF).

As described in Section 5.6, approximately 6 acres of soils would be permanently impacted by construction of the South Platte River Facilities. For Alternative 8a, it was assumed that when Denver Water acquires the gravel pits they would be completely mined and reclaimed for use as an empty water storage facility. Temporary impacts to soils, however, would result from construction activity associated with the inlet/outlet works at the gravel pits. Since Conduit O would be constructed in existing roads and other right-of-ways (ROWs) (except at stream crossings), soils would not be incrementally affected by the Project. Overall, it is not anticipated that soils would be cumulatively affected in the Project area under Alternative 8a.

4.6.6.4 Alternative 10a with Reasonably Foreseeable Future Actions

The total environmental effects to soils at Gross Reservoir would be the same as those described for Alternative 8a.

As described in Section 5.6, approximately 19 acres of soils would be permanently impacted by construction of the Denver Basin Aquifer Facilities. Soils in the Project area are not anticipated to be cumulatively impacted from construction of the Denver Basin Aquifer Facilities under Alternative 10a because the areas of Denver where construction would occur are already highly urbanized and developed. Minimal cumulative impacts to soils would result from construction of Conduit M since the pipeline would be constructed curb-to-curb in existing roads and ROWs (except at stream crossings). Conduit M would cross undeveloped areas in Arvada that may be developed into commercial, office, or light industrial uses. Additionally, portions of Jefferson County within the Conduit M alignment are transitioning from suburban to more urban uses (mixed commercial/residential).

4.6.6.5 Alternative 13a with Reasonably Foreseeable Future Actions

The total environmental effects to soils at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (60,000 AF).

The total environmental effects to soils for the South Platte River Facilities are the same as those described above for Alternative 8a.

4.6.6.6 No Action Alternative with Reasonably Foreseeable Future Actions

There are no ground-disturbing activities associated with the No Action Alternative; thus no cumulative impacts to soils would occur.

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4.6.7 Vegetation

This section describes effects to upland vegetation, noxious weeds, and sensitive plant communities that exist in the Moffat Collection System Project (Moffat Project or Project) area. The Proposed Action with reasonably foreseeable future actions (RFFAs), including past, present, and future diversions, would have no effects to upland vegetation along the river segments. Potential cumulative effects to riparian and wetland vegetation are discussed in Section 4.6.8. The affected environment for vegetation is described for Current Conditions (2006) in Section 3.7. This cumulative impacts analysis evaluates the potential effect of each Project alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other RFFAs. The potential total effects to vegetation are evaluated against Current Conditions (2006).

4.6.7.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Past regional population growth and development in the Front Range has mostly occurred east of the foothills, but has had some effect on the Gross Reservoir area. In addition to areas around the existing Gross Reservoir, the principal developments that have occurred are large-acre residential areas, roads, and a railroad. The existing Gross Reservoir occupies 418 acres and occupies an area that was originally a combination of ponderosa pine-Douglas fir forests and riparian shrubs along South Boulder Creek and other creeks. Implementation of the Proposed Action with RFFAs would remove an additional 456 acres of natural vegetation, including about 400 acres of forest and woodland (see Section 5.7). Other than the expansion of Gross Reservoir, there is expected to be a limited amount of loss or modification of vegetation from large-lot mountain home developments, and no new developments are proposed on private land. The area around Gross Reservoir is currently dominated by natural vegetation types and is expected to continue to be mostly natural vegetation. The predominant land-based changes, disturbances, or developments have occurred, or are anticipated to occur, east of the Front Range foothills; therefore, there is little overlap of impacts with activities at Gross Reservoir.

It is likely that much of the Gross Reservoir area has had timber cutting or fires in the past, and there is only a small amount of old growth forest. Suppression of wildfires for several decades has caused an increase in tree densities in ponderosa pine and mixed conifer forests in Colorado and encroachment of Douglas-fir in ponderosa pine forests, resulting in increased fuel loadings and high intensity stand-replacing fires (Colorado State Forest Service 2010). The Gross Reservoir study area is within the Winiger Ridge Project area, a partnership of various governmental and private parties, including the U.S. Forest Service (USFS) and the Board of Water Commissioners (Denver Water), working collaboratively to reduce the potential for catastrophic disease, insect and wildfire incidents. The Winiger Ridge Project area includes the land between Boulder Canyon and Coal Creek Canyon, and has a high fuel level for forest fires and an interspersion of wild lands and human population. Actions have included prescribed burns, noxious weed control, forest thinning, fuelbreaks, pine beetle control, and defensible spaces around homes. The USFS has implemented past vegetation treatment west of Gross Reservoir as part of the Winiger

Ridge Project, and is developing a proposal for future fuels treatment for the Forsythe Fuels Treatment Project.

Ponderosa pine is the most common tree at Gross Reservoir and is susceptible to mountain pine beetle. The mountain pine beetle outbreak that began in 1996 in northern Colorado has mostly affected lodgepole pine but has recently expanded into ponderosa pine forests east of the Continental Divide. In 2010, there were approximately 229,000 acres of ponderosa pine infestation compared to 22,000 in 2009 (Colorado State Forest Service 2011a). Mountain pine beetle activity in ponderosa pine is expected to continue over the next several years, with areas of older and dense trees the most affected. There appears to have been little or no activity in the Gross Reservoir area through 2010, but aerial mapping shows nearby activity in 2010 including north and west of the reservoir in lodgepole pine and limber pine, and southeast of the reservoir in ponderosa pine (Colorado State Forest Service 2011b). Because of wind dispersal, mountain pine beetle may show up in any ponderosa pine stand along the northern Front Range.

In 2010, Denver Water and the USFS announced a plan to equally share an investment of $33 million, over a five year period, for restoration projects on more than 38,000 acres of National Forest lands. Recent wildfires and the State's 3 million acres of pine beetle-infested forests have emphasized the need to protect forest health. This partnership will accelerate and expand the USFS' ability to restore forest health in watersheds critical for Denver Water's water supplies and infrastructure. Forest thinning and other wildfire fuels reduction projects will take place around and upstream of Denver Water reservoirs. Restoration also will help the forests become more resistant to future insect and disease, reduce wildlife risks and maintain habitat for fish and wildlife.

Past and ongoing human activities have caused the introduction and limited spread of several noxious weeds in the Gross Reservoir area. The Proposed Action, along with other human activities in the area, could result in future introduction of the new noxious weeds or spread of species that area already present. Noxious weeds are expected to remain a minor part of the vegetation community because of the limited amount of land disturbance, relative remoteness from heavily infested areas, and unsuitable conditions for many weed species.

The Proposed Action with RFFAs would result in the loss of approximately 5 acres of two globally rare foothills riparian shrubland communities, river birch/mesic forb foothills riparian shrub and thinleaf alder/mesic forb riparian shrubland. It is likely that construction and inundation of the original Gross Reservoir destroyed a larger area of these two plant communities. The original Gross Reservoir inundated approximately 2.5 miles of South Boulder Creek, 1.25 miles of Forsythe Creek, and 1.0 mile of other creeks, about 3 times the stream length that would be inundated by the Proposed Action. RFFAs, including future population growth and development, are likely to have limited additional effects on these communities because they occur along creeks, which are largely protected from development except for road and utility crossings. In addition, some occurrences are protected on open space or public lands.

4.6.7.2 Alternative 1c with Reasonably Foreseeable Future Actions

The types and sources of cumulative impacts at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs and would affect the same plant communities. Impacts at Gross Reservoir would be less because the reservoir would be smaller and would affect about 360 acres of vegetation, including 337 acres of forest and woodland. Inundation of the Colorado Natural Heritage Program (CNHP) listed communities, water birch/mesic forb foothills riparian shrub and thinleaf alder/mesic forb riparian shrubland, would be about 25% less than described for the Proposed Action with RFFAs, and would total about 3.8 acres.

Construction of a new reservoir at Leyden Gulch would result in direct impacts of 555.0 acres of vegetation, including 383.2 acres of permanent impacts and 171.8 acres of temporary impacts. The vegetation types that would be affected are predominantly grass/forb rangeland with small inclusions of cottonwoods, herbaceous riparian, snowberry/shrub mix, disturbed rangeland, and disturbed soil areas. The direct and indirect impacts of the Moffat Project with RFFAs, when combined with the impacts of possible transportation improvements and urban development in Jefferson County, would result in minor to moderate cumulative impacts to vegetation. The Leyden Gulch Reservoir site is within the expected growth corridor of the northwest Denver Metropolitan area, and most of the impacts would be the result of vegetation losses in future development footprints. The primary vegetation communities that would be affected cumulatively include grass/forb rangeland with small inclusions of cottonwoods, herbaceous riparian area, disturbed rangeland, and existing disturbed soil areas. Future vegetation north and west of Leyden Gulch is expected to remain similar to existing conditions because these areas are managed as open space. Areas to the south and east of the Leyden Gulch Reservoir site are private and may undergo much larger changes as urban development occurs.

Past land management activities at the Leyden Gulch Reservoir site have resulted in noxious weeds being prevalent throughout the Leyden Gulch Reservoir site. Grading and other construction-related activities in the vicinity of the Leyden Gulch Reservoir site and future urban and transportation developments have the potential to increase noxious weed infestations.

4.6.7.3 Alternative 8a with Reasonably Foreseeable Future Actions

The types and sources of cumulative impacts at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs and would affect the same plant communities. Impacts at Gross Reservoir would be less because the reservoir would be smaller and would affect about 414 acres of vegetation, including 388 acres of forest and woodland. Inundation of CNHP listed communities, water birch/mesic forb foothills riparian shrub and thinleaf alder/mesic forb riparian shrubland, would be about 4.3 acres, slightly less than described for the Proposed Action with RFFAs.

Due to the existing disturbed conditions present throughout the area of the South Platte River Facilities, Alternative 8a would result in very little, if any, change in overall vegetative condition. Because the proposed gravel pits are anticipated to be kept full with little seasonal fluctuation, it is likely that areas adjacent to the shoreline would re-establish with riparian or wetland species. Overall, there would be minor cumulative effect to vegetation resources at the South Platte River Facilities.

The loss of vegetation as a result of conduit construction and future development activities would result in a minor short-term (3 to 5 years) cumulative impact to vegetation resources. Long-term cumulative effects would include the loss of mature trees along the pipeline rights-of-way and potentially in adjacent areas where other development projects may occur.

4.6.7.4 Alternative 10a with Reasonably Foreseeable Future Actions

The types and sources of cumulative impacts to vegetation at Gross Reservoir would be the same as those described Alternative 8a.

The primary impacts to vegetation throughout the Denver Basin Aquifer System would include the permanent conversion of grass and turf areas within the City and County of Denver's public properties (primarily park lands) to impermeable surfaces (e.g., buildings, well sites). Although the conversion would result in permanent site-specific impacts to vegetation, overall, the impacts on vegetation resources throughout the City and County of Denver's properties would be negated by proposed future recreational improvements and open space preservation efforts. As such, there would be little to no cumulative impacts to vegetation on City and County of Denver's public property under Alternative 10a.

4.6.7.5 Alternative 13a with Reasonably Foreseeable Future Actions

The types and sources of cumulative impacts at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs and would affect the same plant communities. Impacts at Gross Reservoir would be less because the reservoir would be smaller and would affect about 460 acres of vegetation, including 428 acres of forest and woodland. Inundation of CNHP listed communities, water birch/mesic forb foothills riparian shrub and thinleaf alder/mesic forb riparian shrubland, would be about 4.6 acres, slightly less than described for the Proposed Action with RFFAs.

Due to the existing disturbed conditions present throughout the area of the South Platte River Facilities, Alternatives 13a would result in very little, if any, change in overall vegetative condition. Because the proposed gravel pits are anticipated to be kept full with little seasonal fluctuation, it is likely that areas adjacent to the shoreline would re-establish with riparian or wetland species. Overall, there would be minor cumulative effect to vegetation resources at the South Platte River Facilities.

Agricultural water rights transfers, when combined with RFFAs that result in the conversion of irrigated cropland to fallow fields or impermeable surfaces, would result in minor to moderate cumulative effects to vegetation resources in the immediate vicinity of the transfers. The combined effects of agricultural conversion and development disturbance would increase the distribution and cover of noxious weeds. Relative to the rate at which these lands are being converted in northern and eastern Colorado, the Project's contribution to the cumulative effects would be negligible to minor under Alternative 13a.

4.6.7.6 No Action Alternative with Reasonably Foreseeable Future Actions

The No Action Alternative would not contribute to cumulative impacts to vegetation in the Gross Reservoir area. The only impacts would be more frequent and prolonged drawdowns, which may provide a potential for increased noxious weed infestations. Other contributors to cumulative impacts would be the same as described for the Proposed Action with RFFAs, including limited large lot residential development, increased fuel loadings in forests, mountain pine beetle, and management of forest health.

With the exception of mandatory restrictions imposed during Stages 3 and 4 drought periods, vegetation resources throughout the greater Project service area would remain largely unchanged under the No Action Alternative. Lawn watering would be prohibited in both Stage 3 and 4 droughts, and non-native lawn species and ornamental landscaping would be impacted by the mandatory restrictions. Trees, shrubs, and high-use public turf areas would be limited to watering once per week. This would result in temporary stresses to irrigation dependent vegetation, however, these areas should recover once restrictions are removed. Under Stage 4 drought restrictions, all outdoor watering is prohibited, including trees, shrubs, and high-use public turf areas. Mortality, although impossible to quantify, is likely in some irrigation dependent areas.

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4.6.8 Riparian and Wetland Areas

The affected environment for riparian and wetland areas is described for Current Conditions (2006) in Section 3.8. This cumulative impacts analysis evaluates the changes in riparian and wetland areas due to each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to riparian and wetland areas are evaluated against Current Conditions (2006).

Construction and Inundation

Impacts to waters of the United States (U.S.), including wetlands, are subject to review by the U.S. Army Corps of Engineers (Corps) under Section 404 of the Clean Water Act (CWA). Any project that includes the placement of dredged or fill material into waters deemed jurisdictional by the Corps must obtain a Section 404 Permit prior to the activity. Depending on the specific Section 404 authorization, the Corps may also be required to determine that potential impacts have been avoided or minimized to the maximum extent practicable and remaining unavoidable impacts have been mitigated to maintain no overall net loss of wetlands. This Environmental Impact Statement (EIS) provides the basis for regulatory review of the Section 404 Permit application for the Moffat Project. Appendix K contains a detailed Section 404(b)(1) analysis conducted by the Corps. Section 5.8 addresses construction and inundation impacts from the Moffat Project alternatives.

Direct permanent impacts can result from clearing, excavating, inundation, filling, and/or other grading that would modify the existing functions of these areas. This would include installation of riprap or other materials. Project impacts were assessed by overlaying the footprint of the facilities and construction area on maps of wetlands and other water features. Direct impacts of other RFFAs were assessed qualitatively because quantitative impacts were mostly not available. RFFAs activities outside of the Gross Reservoir area were not considered to have a cumulative effect to riparian and wetlands areas at Gross Reservoir.

Indirect permanent impacts to wetlands and riparian zones include constriction of stream flow from open-cut trenching, erosion resulting from sedimentation, hydrologic modifications as a result of earthwork in adjacent areas, off-highway vehicle use, or noxious weed invasion. Indirect impacts were assessed qualitatively.

Temporary impacts are associated with construction access among other things, and generally do not have long-term impacts on wetland hydrology and/or function. Construction impacts would occur in temporary use areas and construction access roads and would be relatively minor and localized. Construction impacts may include cutting and covering vegetation to facilitate construction adjacent to wetlands, or temporarily placing fill into a wetland area. The topography and hydrology of temporarily affected areas would be re-established after construction, which would promote wetland and riparian vegetation.

Herbaceous wetlands would re-establish relatively quickly, while impacts to riparian woodland would take much longer to restore.

Stream Flow Changes

All of the action alternatives and the No Action Alternative would involve change in the Board of Water Commissioners' (Denver Water's) management of its existing system that would result in flow changes in the Fraser River and its tributaries, Williams Fork River and its tributaries, Colorado River, Blue River, South Boulder Creek, North Fork South Platte River, and the South Platte River. Changes in average, wet-year and dry-year flows are provided in Appendix H and discussed in Section 4.6.1.

Stream flow is a major influence on riparian vegetation, by providing moisture as well as being the predominant agent of landscape change and natural disturbance. Much of the variability and complexity of riparian landscape is driven by fluvial processes, resulting in a complex mosaic of variations in inundation and soil moisture, topography and geomorphology, substrate characteristics, disturbance, and nutrients (Ward et al. 2002; Naiman et al. 2005; Merritt et al. 2009). Riparian systems are also influenced by the characteristics of their watersheds, including geology, slope, sediment size, vegetation cover, and groundwater (Naiman et al. 2005; Engelhardt et al. 2011; Vidon and Hill 2004). River corridors, especially in mountain areas, often consist of a sequence of constrained and unconstrained channels where canyons with narrow bands of riparian vegetation alternate with alluvial valleys that have more riparian vegetation and high groundwater. In addition, climate influences riparian systems. Streams whose discharge is primarily snowmelt have smaller peak flows and lower year to year variability than streams with discharge dominated by rainfall (Ryan and Caine 1993). Discharges in subalpine streams are typically 2-3 times bankfull flow, while floods in rainfall regimes can be 10 times or more greater than bankfull flow.

Maintenance of the hydrology to support riparian vegetation is therefore the result of complex interactions between surface flows, groundwater, precipitation, and the physical characteristics of a stream channel and the floodplain it occupies. For this reason, it is difficult to establish simple cause and impact relationships between stream flow and riparian vegetation. Given this complexity and the large geographic area where stream flow modifications would occur, the impact assessment focused on two primary mechanisms that may affect riparian vegetation:

- Lowering of groundwater tables to a degree that causes plant mortality (e.g., plants are no longer able to extend roots deep enough to reach the water source upon which they depend).
- Changes in the width of bank area regularly inundated by stream flows, resulting in more xeric conditions near the active stream channel.

Research on the relationships between flow modifications and riparian vegetation was reviewed for the analysis, as well as the conclusions of the groundwater investigations conducted as part of the Moffat Project EIS. Although major impacts to riparian systems in the West have been documented as a result of stream flow modifications (Stine et al. 1983), these are usually in situations where diversions resulted in complete dewatering of the stream, profound changes in flows, or major modifications to stream hydrology resulting from gravel mining or other types of disturbance. This level of flow change or modifications to stream channels is not predicted to result from the Moffat Project. Since the Moffat Project is designed to capture surface water flows only during periods of higher runoff in wet or average years, increased diversions are not anticipated for dry years or during periods of low flows. In addition, flow modifications resulting from the Project are within the range of normal variability (i.e., flows already vary substantially from dry years to wet years and over the course of a season).

Groundwater

Surface water and groundwater are linked together in river corridors, forming a single hydrological system across the valley fill (Naiman et al. 2005). Water is continually exchanged between the river, riparian aquifer and regional aquifer. The interface between surface water and groundwater along streams is called the hyporheic zone. As stated in Winter et al. (1998) "streambeds and banks are unique environments because they are where ground water that drains much of the subsurface of landscapes interacts with surface water that drains much of the surface of landscapes."

Streams interact with groundwater in three basic ways – they gain water through groundwater discharge (gaining stream), they lose water to groundwater through the streambed (losing stream), or they both gain and lose in different reaches or different seasons (Winter et al. 1998). In gaining reaches, alluvial groundwater and stream surface elevation (stage) are not as closely connected as they are in losing reaches. Most streams outside of arid and semi-arid areas are gaining streams, although the amount of groundwater contribution to overall flow is variable (Winter et al. 1998). Riparian vegetation and alluvial groundwater along losing streams in arid and semi-arid areas are primarily supported by stream flows and these systems are particularly sensitive to reductions or changes in the amount, duration, or timing of flows. A number of studies have been done on the effects of changes in surface water flows in riparian areas along lower elevation rivers in the arid southwestern States (e.g., Shafroth and Beauchamp 2006; Merritt et al. 2010), but the conclusions of those studies do not necessarily apply to the Moffat Project. All of the rivers and streams in the Moffat Project river segments study area are likely gaining streams, which are less sensitive to changes in surface flows.

The primary source of water for montane and subalpine wetlands and riparian habitats in Colorado is snowmelt, which reaches the wetlands via stream flow, melting on site, groundwater movement and overland flow (Dougherty et al. 1987). Most of the snowmelt from uplands reaches the wetlands and riparian areas in the valley bottoms by groundwater movement through fractures and upland soils. Movement through saturated soils is relatively fast while percolation to the water table and subsequent movement to the stream takes longer. The shape of the water table in the regional aquifer generally follows surface topography. Where the regional aquifer intercepts the ground surface, such as along lower slopes and the edges of floodplains, the high water table supports wetlands, including fens in some areas. Groundwater in alluvial valleys may also be supported by interactions including overbank flooding, bank storage during high water, and channel damming by beaver activity or ice jams. As long as the rise in stage does not overtop the streambanks, most of the water that enters the banks during high flows returns to the river within a few days or weeks (Winter et al. 1998). If larger areas are flooded, the water table is recharged over a larger area and water may take much longer to return to the stream depending on the length of the groundwater flow paths.

A study of the interaction of groundwater, streams, and wetlands was conducted for the Moffat Project (refer to Section 3.4). This study included monitoring of stream levels and groundwater in wells in October 2010 and during high flow in June and July of 2011 along Jim Creek, St. Louis Creek, and the Fraser River. In addition, groundwater and surface water data previously collected by Grand Environmental Service (2009) at Winter Park were analyzed. The data show that groundwater moves from topographically elevated areas toward the rivers during both low and high stream flows, and that wetland areas more than a few feet above the Fraser River are supported by groundwater and not by stream flow. Groundwater levels approach stream levels along the stream banks where groundwater and surface water mix.

The groundwater analysis in Sections 4.6.4 and 5.4 indicates that flow changes along the river segments would cause localized minimal effects to the water table that would not be any larger than stream elevation changes. As described below, hydraulic modeling was used to assess potential changes in flood elevations and widths for each river segment. Groundwater levels and discharge from regional and local aquifers would remain the same except for a slight increase in discharge to the stream in gaining reaches. The water table fluctuations would be well within the range of normal seasonal fluctuations. Drought conditions would reduce groundwater elevations throughout the region but groundwater would continue to flow toward the rivers.

Although more applicable to lower elevation sites, such as the cottonwood stands along the Colorado and South Platte rivers, prior studies have documented that declines of 1 foot or more in the water table are required before deciduous riparian vegetation is adversely effected. A study in Colorado concluded that a water table decline of 1 meter or more resulted in approximately 88% cottonwood mortality, while declines of less than 0.5 meter did not lead to increased mortality (Scott et al. 1999, 2000).

Change in Inundated Area

The second primary mechanism for impacting riparian vegetation is modification of stream stage and a reduction of the bank area that is regularly inundated in the vicinity of the stream channel. Riparian systems typically exhibit lateral zonation of plants species that are related to depositional features such as active channel bars and terraces that represent increasingly higher levels above the wetted surface and that have corresponding decreases in flooding duration and frequency (Naiman et al. 2005). Auble et al. (1994) state that there is a clear relationship between inundation duration and the type of vegetation present and suggest that changes in inundation duration can be used to predict vegetation change. Stromberg et al. (2005) found that hydric riparian plants declined sharply in cover with loss of perennial stream flow, but cover of mesic riparian perennials increased at sites with reduced flow. This type of response could occur at locations within the Moffat Project study area, though it would be modified by differences in climate at the wetter sites found in the montane and subalpine settings of the upper Fraser and Williams Fork rivers. In addition, the presence of groundwater discharge in gaining reaches is likely to reduce the relative effect of changes in stream flow.

A review of the literature on ecological responses to altered flow regimes (Poff and Zimmerman 2010) did not find any consistent trend of riparian response to alteration in flow magnitude, although their findings did suggest that larger changes in flow alteration were associated with greater risk of ecological change. Ecological responses reported from flow stabilization (loss of peak flows) included failure of seedling establishment, terrestrialization of flora, increased success of non-native species, vegetation encroachment into channels, and increased riparian cover.

Changes in flood extent were modeled using the Corps Hydrologic Engineering Centers-River Analysis System (HEC-RAS) computer software (version 4.0) for analysis of stream hydraulics. A HEC-RAS model was developed for each Representative reach using data collected in the field, including stream discharge, velocity, slope, and channel geometry data. For more detailed information on the data collected, refer to the Moffat Collection System Project Existing Channel Conditions Report (ERC 2006). The HEC-RAS hydraulic models were used to generate water surface-profiles and other hydraulic output as a function of discharge for each reach. For each Representative reach, the HEC-RAS modeled was simulated for the 1.5-, 2-, 5-, and 10-year flood events for each EIS scenario (Current Conditions, Full Use of the Existing System, No Action Alternative, and each EIS action alternative). Probability plotting was relied on to estimate the flood flow rates for the recurrence intervals evaluated. The probability plot flows are provided in Table 4.6.8-1. HEC-RAS output was used to determine changes in water surface elevations and differences in the width of channel that would be inundated. The results are summarized in tables in this section and in Section 5.8.

Table 4.6.8-1
Probability Plot Flow Events

Sampling Site	Recurrence Interval (years)	Flow Rates (cfs)							
		Current Conditions (2006)	Full Use of the Existing System	Proposed Action with RFFAs	Alt. 1c with RFFAs	Alt. 8a with RFFAs	Alt. 10a with RFFAs	Alt. 13a with RFFAs	No Action Alter-native
FR1	2	150	136	54	54	70	69	70	113
	5	262	249	212	216	214	212	215	235
	10	359	362	274	286	275	275	275	330
FR2	2	856	824	659	660	660	660	659	821
	5	1,264	1,211	1,167	1,173	1,167	1,169	1,169	1,179
	10	1,639	1,652	1,454	1,454	1,455	1,455	1,454	1,649
FR3	2	190	188	154	155	158	158	158	190
	5	299	299	278	278	278	278	278	296
	10	335	335	335	335	335	335	335	335
FR4	2	77	77	68	68	70	70	70	77
	5	101	101	101	102	101	102	102	101
	10	126	126	126	126	126	126	126	126
WF1	2	324	324	324	324	324	324	324	324
	5	414	414	414	414	414	414	414	414
	10	463	463	463	463	463	463	463	463
	10	292	292	292	292	292	292	292	292

Table 4.6.8-1 (continued)
Probability Plot Flow Events

Sampling Site	Recurrence Interval (years)	Flow Rates (cfs)							
		Current Conditions (2006)	Full Use of the Existing System	Proposed Action with RFFAs	Alt. 1c with RFFAs	Alt. 8a with RFFAs	Alt. 10a with RFFAs	Alt. 13a with RFFAs	No Action Alter-native
WF2	2	205	205	202	202	202	202	202	205
	5	276	276	276	278	276	278	278	276
CR1	2	826	618	610	610	610	610	610	610
	5	2,696	2,362	2,235	2,299	2,235	2,276	2,276	2,254
	10	3,490	3,496	3,294	3,287	3,354	3,355	3,321	3,456
BR1	2	1,910	1,511	1,358	1,351	1,358	1,358	1,350	1,173
	5	2,335	2,272	2,282	2,275	2,287	2,275	2,275	2,242
	10	2,430	2,380	2,402	2,400	2,402	2,400	2,400	2,304
SBC1	2	852	882	944	944	944	944	944	888
	5	984	985	993	993	993	993	993	988
	10	1,003	1,003	1,015	1,015	1,015	1,015	1,015	1,003
SBC3	2	645	645	574	604	574	574	574	674
	5	741	766	687	751	690	689	688	750
	10	821	834	737	823	735	735	745	815
NF1	2	540	628	636	636	635	636	636	636
	5	638	654	656	656	656	656	656	656
	10	645	667	668	668	668	668	668	666
NF2	2	626	652	683	683	683	683	682	669
	5	762	763	772	773	772	773	773	763
	10	838	838	838	838	838	838	838	838

Note:
RFFA = reasonably foreseeable future action

For this section of the EIS, use of HEC-RAS output focused on 2-year runoff events, which generally correlate with bankfull conditions. It is recognized that 2-year flows play an important role in establishing and maintaining riparian wetlands. In their work on the Greybull River in Wyoming, Johnson et al. (1999) state that the 2-year floodplain can be assumed to be the outer limit of the wetland area potentially affected by the stream diversions. They further state that the peak flows that occur every 2 years provide inflow to depressions and low areas with enough frequency to potentially establish wetland hydrology. Reductions in the 2-year flow could result in a gradual narrowing of the stream channel as vegetation establishes on channel bars. Although the new vegetation would have wetland hydrology, it was conservatively assumed that narrowing of the channel would result in a loss of wetlands at the periphery of the channel. This assumption would not be correct where there is a significant amount of groundwater discharge.

This type of change was observed by Ryan and Caine (1993), who investigated the effects of diversions on channels in mountain streams using St. Louis Creek as the primary study area. In unconfined stream reaches, they found a loss of channel surface due to infrequent inundation of channel bars, vegetation colonization of stable channel surfaces, and development of a low, vegetated surface below a formerly active cutbank. These changes occurred only on wide valley floors with gravel to cobble beds, slopes ranging from 1 to 2%, and banks vegetated by grasses and willows. They found no changes in confined stream reaches. They also found that longer-term return floods have the potential to reset the system so that there is no loss of channel width, by disturbing vegetation that has established in the channel, washing fines from gravel and cobble beds, and restructuring channel topography. Further information on channel changes is provided in the geomorphology analysis in this EIS (Section 4.6.3). The geomorphology study included three methods of analysis of whether past diversions had resulted in channel changes and summaries of other previous studies on channel morphology.

Results for the 5- and 10-year return flows in this analysis are also presented as an estimator of the potential effects of impacts to riparian vegetation located above the bankfull flow. These represent overbank flow onto the active floodplain. Chapin et al. (2002) found that the 3 to 7 year return intervals have effects on the distribution of riparian plant species in a semi-arid river basin where stream flow was the primary source of hydrology. Longer return flows (>10 years) were not analyzed for the EIS but can have major effects through catastrophic destruction of riparian plant communities, creation of new floodplain surfaces, and channel movement.

Changes in Wetland Functions

Potential changes in wetland functions at the sample sites were assessed qualitatively using the Corps Functional Assessment of Colorado Wetlands (FACWET) method (Johnson et al. 2011). This method uses scores for 9 variables, which are then combined to determine effects on 7 functions. The scores are based on assessment of the presence and degree of stressors that have changed a function from its original condition. Changes in scores were estimated at each sample site based on the types of impacts that would occur. The nine variables are listed below, along with notes on application of the FACWET method to this Project. Estimated impacts to the seven functions are assessed in the analysis of impacts for each sample site.

- **Variable 1: Habitat Connectivity – Neighboring Wetland Loss** – There would be no change in this variable. Stream flow changes at all of the sites would not have adverse effects on wetlands away from the river edge in the 500-meter-wide habitat connectivity envelope.
- **Variable 2: Habitat Connectivity – Migration/Dispersal Barriers** – There would be no change in this variable. Stream flow changes at all of the sites would not cause changes in existing stressors such as roads and bike paths.
- **Variable 3: Buffer Capacity** – There would be no change in this variable. Stream flow changes at all of the sites would have no effect on land uses within a 250 meter buffer area.
- **Variable 4: Water Source** – Additional diversions or augmentation would change the amount of water and seasonal flow patterns at the sample sites. Existing depletions put these rivers into the functioning category (mild to moderate drawdown or uniform depletion up to 50%), except for some of the Fraser River tributaries which are non-functioning.

- **Variable 5: Water Distribution** – At all sites, changes in stream flow would not involve changes in stressors such as culverts, ditches, weirs, levees, etc. Possible changes considered include alteration of water source (flood height/width), channel incision/entrenchment and sediment/fill accumulation, and elevation of the water table. The area affected would be less than 10% of riparian habitat at all sites. Existing groundwater supports most of riparian area at some sites and would reduce the impact of changes in distribution caused by stream flows.
- **Variable 6: Water Outflow** – At all sites, changes in flow would affect transportation of materials and energy downstream, but other stressors would not change.
- **Variable 7: Geomorphology** – Water flow changes could affect channel geomorphology, which is analyzed in Section 4.6.3. Potential stressors considered were channel instability/overwidening, excessive bank erosion, channelization, reconfigured stream channels, and substrate embeddedness.
- **Variable 8: Water and Soil Chemical Environment** – Riparian zones act as filters that protect stream water quality from upland runoff that contains sediment, nitrates and other nutrients, and also affect nutrient levels in adjacent streams. Shading by riparian vegetation moderates water temperatures. Final EIS Section 4.6.2 addresses water quality in more detail.
- **Variable 9: Vegetation Structure and Complexity** – For all sites, potential stressors relating to changes in water flow include dewatering and oversaturation. Changes in wetting patterns were estimated by HEC-RAS results and flow duration curves. Changes in vegetation composition would occur on portions of some sites.

Impacts to wetlands, other waters of the U.S., and riparian habitats are discussed below by alternative and facility.

4.6.8.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Past actions that have affected wetlands and riparian vegetation in the Gross Reservoir study area include construction of the existing Gross Reservoir, increases in flow in South Boulder Creek from diversions in the Fraser and Williams Fork valleys, and minor changes from installation of culverts at road crossings. The Proposed Action with RFFAs would result in direct and permanent impact to 1.95 acres of wetlands and 4.1 acres of riparian habitat, and 8,180 feet of perennial streams, from construction and inundation. Impacts would mostly occur from inundation of creek inlets and the existing shoreline. RFFAs are not likely to have adverse effects on wetlands and riparian areas at Gross Reservoir, beyond those associated with the Moffat Project alternatives, because no major actions that would impact wetlands or riparian areas are planned in these areas. In addition, direct permanent losses of wetlands are unlikely because of mitigation and permitting requirements under Section 404 of the CWA. A more detailed evaluation of Project impacts at Gross Reservoir is provided in Section 5.8.

For the river segments, past water-related actions, including impoundments, diversions, and inter-basin transfers, have affected stream flows and may have had adverse effects on the extent and type of wetland and riparian areas along the rivers. Clearing of riparian areas to create agricultural land in the larger river valleys and use of irrigation have also affected the type and amount of riparian habitats. Historic reductions in stream flows, particularly seasonally high flows, reduced the extent and duration of flooding within the 2-year channel and backwaters, and well as the extent of overbank flooding. These past changes resulted in changes in the extent or composition of riparian vegetation including increased growth of upland species. More recent changes have included development of irrigated land, which has the potential to affect the distribution and availability of both surface and groundwater. The survey data collected for the Grand County Stream Management Plan provides a general assessment of the existing conditions of riparian habitat along major streams in Grand County (Table 3.8-8), but does not address extent of riparian vegetation or composition relative to original conditions. Some stream reaches along the Fraser River, its major tributaries, Colorado River and Blue River have optimal riparian cover/disturbance and width, most are suboptimal, and a few are marginal or poor for cover/disturbance, width or both.

Modeled changes in flood elevations and widths that would result from total environmental effects including the Proposed Action with RFFAs compared to Current Conditions (2006), are shown in Tables 4.6.8-2, 4.6.8-3, and 4.6.8-4. The results for each river segment are discussed below. The elevation and width changes in this and the other tables in this section represent an average of the results from about 14 transects within each Representative reach. The sampling sites represent a small portion of the affected river segments within the study area and results will vary by channel geometry and distance from the diversion, but are considered to be generally representative of the river segment in which they are located.

Table 4.6.8-2
Two-Year Flow Changes for Sampling Sites, Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Sampling Site	Study Segment Length (feet)	Average Channel Width of 2-Year Flow at Current Conditions (feet)	Total Environmental Effects for the Proposed Action with RFFAs Compared to Current Conditions (2006) for the 2-Year Flow Event			
			2-Year Flow Elevation Change (inches)	2-Year Flow Width Change (feet)*	2-Year Flow Area of Change within Study Segment (acres)	2-Year Flow Area of Change (acres per mile)
FR1	539	29.30	-9.47	-4.14	-0.051	-0.50
FR2	872	85.08	-4.13	-6.36	-0.127	-0.77
FR3	335	46.87	-2.03	-1.98	-0.015	-0.24
FR4	571	20.10	-1.00	-0.27	-0.004	-0.03
WF1	590	66.27	0.00	0.00	0.000	-0.00
WF2	590	29.97	-0.21	-0.16	-0.002	-0.02
CR1	953	141.44	-3.51	-2.40	-0.053	-0.29
BR1	1,000	108.89	-13.93	-10.11	-0.232	-1.23

Table 4.6.8-2 (continued)
Two-Year Flow Changes for Sampling Sites, Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Sampling Site	Study Segment Length (feet)	Average Channel Width of 2-Year Flow at Current Conditions (feet)	Total Environmental Effects for the Proposed Action with RFFAs Compared to Current Conditions (2006) for the 2-Year Flow Event			
			2-Year Flow Elevation Change (inches)	2-Year Flow Width Change (feet)*	2-Year Flow Area of Change within Study Segment (acres)	2-Year Flow Area of Change (acres per mile)
SBC1	599	45.82	+2.22	+0.92	+0.013	+0.11
SBC3	446	70.26	-1.99	-4.70	-0.048	-0.57
NF1	300	51.76	+2.48	+1.76	+0.012	+0.21
NF2	778	64.30	+1.32	+0.29	+0.005	+0.04

Notes:
*Change of width includes both sides of river.
RFFA = reasonably foreseeable future action

Table 4.6.8-3
Five-Year Flow Changes for Sampling Sites, Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Sampling Site	Study Segment Length (feet)	Average Channel Width of 5-Year Flow at Current Conditions (feet)	Total Environmental Effects for the Proposed Action with RFFAs Compared to Current Conditions (2006) for the 5-Year Flow Event			
			5-Year Flow Elevation Change (inches)	5-Year Flow Width Change (feet)*	5-Year Flow Area of Change within Study Segment (acres)	5-Year Flow Area of Change (acres) per mile
FR1	539	38.16	-3.60	-4.23	-0.05	-0.51
FR2	872	104.91	-1.67	-4.79	-0.10	-0.58
FR3	335	54.46	-0.88	-1.20	-0.01	-0.15
FR4	571	20.89	0.00	-0.01	0.00	0.00
WF1	590	69.97	0.00	0.00	0.00	0.00
WF2	590	33.80	0.00	0.00	0.00	0.00
CR1	953	181.64	-4.99	-5.71	-0.11	-0.69
BR1	1,000	112.07	-7.26	-3.97	-0.09	-0.48
SBC1	599	47.07	+0.21	+0.08	0.00	+0.01
SBC3	446	72.71	-1.35	-1.34	-0.01	-0.16
NF1	300	53.57	+0.41	+0.30	0.00	+0.04
NF2	778	65.07	+0.08	+0.02	0.00	+0.00

Notes:
*Change of width includes both sides of river.
RFFA = reasonably foreseeable future action

Table 4.6.8-4
Ten-Year Flow Changes for Sampling Sites, Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Sampling Site	Study Segment Length (feet)	Average Channel Width of 10-Year Flow at Current Conditions (feet)	Total Environmental Effects with the Proposed Action with RFFAs for the 10-Year Flow Event			
			10-Year Flow Elevation Change (inches)	10-Year Flow Width Change (feet)*	10-Year Flow Area of Change within Study Segment (acres)	10-Year Flow Area of Change (acres) per mile
FR1	539	42.75	-5.02	-4.74	-0.06	-0.57
FR2	872	128.85	-2.82	-6.29	-0.13	-0.76
FR3	335	56.71	0.00	0.00	0.00	0.00
FR4	571	22.13	0.00	0.00	0.00	0.00
WF1	590	72.48	0.00	0.00	0.00	0.00
WF2	590	34.56	0.00	0.00	0.00	0.00
CR1	953	186.54	-1.73	-1.22	-0.03	-0.15
BR1	1,000	112.57	-6.92	-3.68	-0.08	-0.45
SBC1	599	47.23	+0.27	+0.09	0.00	+0.01
SBC3	446	74.68	-2.09	-2.06	-0.02	-0.25
NF1	300	53.68	+0.54	+0.40	0.00	+0.05
NF2	778	65.44	0.00	0.00	0.00	0.00

Notes:
*Change of width includes both sides of river.
RFFA = reasonably foreseeable future action

Fraser River

Sampling Site FR1

Four sampling sites were established in the Fraser River Basin (FR1, FR2, FR3, and FR4), which includes streams with some of the highest levels of proposed flow modification. At these locations, the FR1 site near Winter Park would have the highest depletion level. Based on the Platte and Colorado Simulation Model (PACSM) output for the Fraser River near Winter Park gage (Table H-1.33, there would be an average flow reduction in June of 49% compared to Current Conditions (2006). In terms of actual flow numbers, the average flow in June would drop from 59 cfs to 30 cfs at the gage. The 2-year flow at FR1 would decrease from 150 to 54 cfs (Table 4.6.8-1). Durations of flows of 50 cfs or less would remain very similar to Current Conditions (2006) at FR1 (Appendix H-9).

The impact of additional diversions would result in a change in stage (stream elevation) for a 2-year flow event (of approximately 9.5 inches [Table 4.6.8-2]). The width of the 2-year flow would be reduced by about 4 feet, about 14% of the width under Current Conditions (2006). The total area within the zone between the existing and simulated stream profile in the sample site would be approximately 0.05 acre. The amount of area affected would remain very small even when extrapolated over a longer distance (e.g., a 1-mile segment would experience a reduction in inundated area of approximately 0.5 acre). The width of the area of reduced inundation, as measured at the sampling site, would be approximately 2 feet on each side of the channel.

The plant community that primarily occurs along the side of the channel is heartleaf bittercress-tall fringed bluebells-arrowleaf ragwort. This herbaceous community typically occurs in narrow bands along flowing streams (Carsey et al. 2003). It is an early seral community that is maintained by frequent disturbance from the 2-year flows. Soils are generally thin and skeletal. This community also occurs on gravel bars in the river. Because it occurs within the area of the 2-year flow, this community is likely to move to stay within the area of the new 2-year flow, as the channel gradually narrows in response to reductions in the 2-year flow. The area currently occupied by this community is likely to be gradually occupied by other riparian species, including Drummond's willow and thinleaf alder. The width of the riparian area could increase about 3 feet because of vegetation encroachment on the channel.

Portions of both Drummond's willow/bluejoint reed grass shrubland and Thinleaf alder – Drummond's willow shrubland may also be affected. Drummond's willow/bluejoint reedgrass occurs on saturated soils, which are likely a result of high groundwater. The change in stream flow could reduce groundwater elevation near the banks and could result in a change in understory composition to be more similar to Drummond's willow/mesic forb. Thinleaf alder- Drummond's willow shrubland is a common community along relatively fast-moving streams with stable shaded streambanks. Reductions in the 2-year flow and narrowing of the stream may cause this community to gradually shift in position.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. Reductions would be proportionately less than for the 2-year flow. The 5-year flow would be reduced from 262 cfs at Current Conditions (2006) to 212 cfs at FR1, and the 10-year flow would be reduced from 359 cfs to 274 cfs. Changes in the 5-year flow would be 3.6 inches in height and about 4.25 feet in width. Changes in the 10-year flow would be about 5 inches in height and about 4.75 feet in width. The 5-year flow would be about 13.5 inches higher than the 2-year flow, and the 10-year flow would be about 17 inches higher. Reductions in the 5- and 10-year flows would primarily affect the Drummond's willow/bluejoint reedgrass shrubland, thinleaf alder –Drummond's willow shrubland, and Drummond's willow/mesic forb shrubland communities adjacent to the river.

While the 2-year flow represents bankfull flow, the 5- and 10-year flows involve overbank flooding. Overbank flooding occurs when flows are large enough to cover portions of the floodplain outside the river banks. The width of overbank flooding would be relatively narrow at FR1, about 9 feet for the 5-year flow and 13 feet for the 10-year flow, and similar to Current Conditions (2006) (9 and 13.5 feet, respectively) (Table 4.6.8-5). The average width of the riparian area, excluding the area within the banks, is about 260 feet under Current Conditions. The area of riparian vegetation therefore extends well beyond the area of flooding associated with the 10-year flow, and the area of overbank flooding would cover less than 5% of the riparian area for the 5- and 10-year flows. The primary source of hydrology for the riparian area is high groundwater. A fen occupies about one-quarter of the sampling site on the west side of the Fraser River. Saturated soils in the fen occur at elevations of several feet above the current river bank, and would not be affected by changes in stream flow. On the east side of the river, the subalpine fir-Engelmann spruce/tall fringed bluebells community extends 30 to 100 feet or more away from the stream, well beyond the area affected by the 10-year flow.

Table 4.6.8-5
Width of Overbank Flooding, Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Sampling Site	Average Width of Overbank Flooding – 5-Year flow (feet)[1]		Average Width of Overbank Flooding – 10-Year flow (feet)[1]		Average Width of Existing Riparian Area (feet)[2]
	Current Conditions (2006)	Proposed Action with RFFAs (2032)	Current Conditions (2006)	Proposed Action with RFFAs (2032)	
FR1	8.9	8.8	13.5	12.8	260
FR2	19.8	21.4	43.8	43.8	535
FR3	7.4	8.2	9.4	11.4	165
FR4	0.8	2.0	1.0	2.3	9
WF1	3.7	3.7	6.2	6.2	270*
WF2	3.8	4.0	4.6	4.8	75*
CR1	40.2	36.9	45.1	46.3	110
BR1	3.2	9.3	3.7	10.1	65
SBC1	1.3	0.4	1.4	0.6	15
SBC3	2.5	5.8	4.4	7.1	24
NF1	1.8	0.4	1.9	0.6	100
NF2	0.8	0.5	1.1	0.9	75

Notes:
[1]Based on Hydrologic Engineering Centers-River Analysis System (HEC-RAS) modeling. Overbank flooding is area between 2-year and 5- or 10-year width. Width includes both sides of stream (approximately half on each side).
[2]Based on mapping of riparian vegetation at sampling sites. Existing riparian does not include stream or gravel bars. Width includes both sides of stream (approximately half on each side).
*Additional areas of riparian vegetation supported by groundwater discharge are located adjacent to but outside of the mapped riparian vegetation in the sampling area.
RFFA = reasonably foreseeable future action

Implementation of the Proposed Action would therefore have minor impacts to wetland or riparian habitats at this site. The riparian area appears to be primarily supported by high groundwater levels, and the influence of stream flows appears to be limited to a very small portion of the sampling site. A small narrowing of the zone of inundation from high flows and localized decreases in the water table along the banks would not cause dramatic changes in riparian structure, but could result in gradual changes in composition in some areas and shifts in position of some communities.

At this sampling site, the Proposed Action with other RFFAs would have moderate impacts to one wetland/riparian function, support of fish/aquatic habitat. (Note: this analysis addresses only wetland function; impacts to the fish and aquatic biological resources habitat are evaluated in Section 4.6.11.) It would have minor effects to several other wetland and riparian functions, including flood attenuation, short- and long-term water storage, and production export/food chain support. Impacts to other functions would be negligible. The amount of shading of the stream is not likely to change. Here and at the other sites, changes in functions would be localized along the edge of the river and would not affect wetlands or riparian areas that are more than a short distance away from the river, or that are primarily supported by groundwater or flow from undiverted tributaries.

Sampling Site FR2

The Fraser Canyon Reach (FR2) is located approximately 1 mile downstream of Tabernash and consists of a study reach length of 872 feet. Based on PACSM results for Fraser River below Crooked Creek (Table H-1.49), average flows would be reduced during the spring runoff season (May-July), with average flow in June diminished by 21% at this location, from 492 to 388 cfs. The 2-year flow would be reduced from 856 cfs to 659 cfs at this location (Table 4.6.8-1). Durations of flows of 500 cfs or less at FR2 would remain similar to Current Conditions (2006) (Appendix H-9).

The stream elevation of the 2-year flow would drop by approximately 4 inches (Table 4.6.8-2). The width of the 2-year flow would be reduced by about 6.5 feet, about 7.5% of the width under Current Conditions (2006). Expressed in terms of area, the reduction in inundated area in the sampling site would amount to approximately 0.1 acre, or when extended over a 1-mile distance, the area becomes 0.8 acre. The width of the area of reduced inundation, as measured at the sampling site, would be approximately 3.2 feet on each side of the channel.

Vegetation along the side of the channel is narrow strips of bluejoint reedgrass herbaceous community adjacent to the stream, and the edge of the Geyer willow-mountain willow-bluejoint reedgrass community that occupies much of the sampling site. There are several small side channels or overflow channels dominated by beaked sedge herbaceous vegetation. The narrow strips of bluejoint reedgrass herbaceous vegetation along the edge of the channel are likely maintained by disturbance associated with the 2-year flow and are likely to continue to exist along the edge of the narrower channel. As the channel narrows, the areas currently occupied by these communities are likely to be occupied by other riparian species, especially Geyer's willow and mountain willow. Reduced inundation or localized deepening of the water table may cause the beaked sedge herbaceous vegetation to be replaced by bluejoint reedgrass or other species that can tolerate somewhat drier conditions. The riparian shrub communities that occupy most of the sampling site are generally above the zone that would be affected by the 2-year flow. Where they are within the 2-year flow there may be a shift in the herbaceous vegetation toward more mesic species. The existing shrubs are likely to adapt to somewhat drier conditions, but may gradually change in composition to include more mesic species such as shrubby cinquefoil and conifers.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. Reductions would be proportionately less than for the 2-year flow. The 5-year flow would be reduced from 1,264 cfs at Current Conditions (2006) to 1,167 cfs, and the 10-year flow would be reduced from 1,639 cfs to 1,454 cfs. Changes in the 5-year flow would be about 1.7 inches in height and 4.8 feet in width, a reduction of about 4.5% of stream width. Changes in the 10-year flow would be a reduction of about 3 inches in height and about 6.3 feet in width. The 5-year flow would be about 10 inches higher than the 2-year flow, and the 10-year flow would be about 14 inches higher. Reductions in the 5- and 10-year flows would occur primarily in the Geyer willow-mountain willow/bluejoint reedgrass community. Smaller areas of mountain rush herbaceous vegetation, and wolf willow-mesic forb shrubland would also be affected.

The average width of the riparian area affected by overbank flooding would be about 21 feet for the 5-year flow and 44 feet for the 10-year flow, generally similar to Current Conditions (2006) (20 and 44 feet, respectively). The width of current riparian vegetation is about 535 feet. The area of current riparian and wetland vegetation therefore extends well beyond the flooding associated with the 10-year flow, and overbank flooding would cover less than 5% of the riparian zone for the 5-year flow and less than 10% for the 10-year flow. The primary source of hydrology for the riparian vegetation appears to be groundwater. Wetlands are present along the base of the slopes about 200-300 feet north of the river, outside of the study site.

Changes in flow at this sampling site would result in minor changes to wetland and riparian habitat including changes in composition to more mesic species in areas adjacent to the stream. The Proposed Action combined with other RFFAs would have minor effects to several wetland and riparian functions, including support of fish/aquatic habitat, flood attenuation, short- and long-term water storage, and production export/food chain support. Impacts to other functions would be negligible. The existing riparian vegetation provides minimal shading of the stream and this would not change.

Sampling Site FR3

This site is located on St. Louis Creek above the Town of Fraser (Figure 3.0-2). Based on the PACSM output for St. Louis Creek below Denver Water's diversion (Table H-1.40), average monthly flow reductions would be less than at the mainstem Fraser site, reaching a maximum of 27% in June. Average June flow would drop from 40 cfs under Current Conditions (2006) to 29 cfs below the diversion. The 2-year flow would be reduced from 190 cfs to 154 cfs at FR3 (Table 4.6.8-1). Durations of flows of 100 cfs or less would remain very similar to Current Conditions (2006) at FR3 (Appendix H-9). About 11% of days from May through July would have a decrease of 50 cfs or more at the gage.

The stream elevation of the 2-year flow would drop by about 2 inches, compared to Current Conditions (2006) (Table 4.6.8-2). The width of the stream would be reduced by about 2 feet, a reduction of about 4% of the bankfull stream width under Current Conditions. The reduction in inundated area over the length of the 335-foot segment that was evaluated would be approximately 0.02 acre. If extrapolated over a distance of 1 mile, the Area of Potential Effects increases to approximately 0.2 acre. The width of the area of reduced inundation, as measured at the sampling site, is approximately 1 foot on each side of the channel.

The plant communities that mostly occur along the edge of the channel are heartleaf bittercress-tall fringed bluebells-arrowleaf ragwort herbaceous community and thinleaf alder-Drummond's willow shrubland. The herbaceous community is an early seral community that is maintained by frequent disturbance. It is likely to move or expand to stay within the area of the new 2-year flow, if the channel gradually narrows in response to reductions in the 2-year flow. The area currently occupied by this community would be gradually occupied by other riparian species, including Drummond's willow and thinleaf alder. Thinleaf alder-Drummond's willow shrubland is a common community along relatively fast-moving streams with stable shaded streambanks. The small reduction in the elevation of the 2-year flow is not likely to adversely affect individual shrubs along the edge of the stream, but could enable conifers to become established, which could result in a gradual change toward a subalpine fir – Engelmann spruce/thinleaf alder community.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. Reductions would be proportionately less than for the 2-year flow. The 5-year flow would be reduced from 299 cfs at Current Conditions (2006) to 278 cfs, and the 10-year flow would remain the same at 335 cfs. Changes in the 5-year flow would result in reduction of less than 1 inch in height and about 1 foot in width. There would be no changes to the 10-year flow. Reductions in the 5-year flows would occur immediately adjacent to the stream in the thinleaf alder-Drummond's willow shrubland community as well as a portion of an area occupied by Drummond's willow-water sedge.

The width of the riparian area affected by overbank flooding would be about 8 feet for the 5-year flow and 11 feet for the 10-year flow, generally similar to Current Conditions (2006). The width of current riparian vegetation is about 166 feet. The area of current riparian and wetland vegetation therefore extends well beyond the flooding associated with the 10-year flow, and overbank flooding would cover only about 5% of the riparian zone for the 5-year flow and about 7% for the 10-year flow. The primary source of hydrology for the riparian vegetation appears to be groundwater. The Drummond's willow-water sedge and thinleaf alder-Drummond's willow shrubland had soils saturated to the surface in September, 2010, at elevations above the stream bank.

Changes in flow at this sampling site would result in minor changes to wetland and riparian habitat including changes in composition to more mesic species in relatively small areas adjacent to the stream. The Proposed Action combined with other RFFAs would have minor effects to several wetland and riparian functions, including support of fish/aquatic habitat, flood attenuation, and short- and long-term water storage. Impacts to other functions would be negligible. The amount of shading of the stream would not change.

Sampling Site FR4

One other site in the upper Fraser River Basin was evaluated (FR4), a site on Ranch Creek just below the confluence with the North Fork of Ranch Creek. This sample site has a limited amount of riparian vegetation because of its topographic setting; it is a Rosgen Type A stream with steep to vertical cuttbanks and riparian vegetation narrowly confined to the margins of the stream (see Section 3.3 for description of Rosgen classification). All of the impacts at this site would result from the Proposed Action with RFFAs. Based on the PACSM output for Main Ranch Creek below Denver Water's diversion (Table H-1.47), average monthly flows in June would drop from 20 cfs to 16 cfs, a 22% reduction. Reductions in flow would mostly occur in May, June, and July and there would be little or no change during the remainder of the year below the diversion. The 2-year flow would be reduced from 77 to 68 cfs at FR4 (Table 4.6.8-1). Durations of flows of 25 cfs or less would remain very similar to Current Conditions (2006) at FR4 (Appendix H-9).

The stream elevation of the 2-year flow would drop by approximately 1 inch (Table 4.6.8-2), and the width of the stream would be reduced by about 0.25 feet, a reduction of about 1% of stream width under Current Conditions (2006). The reduction in inundated area over the length of the 571-foot segment that was evaluated would be less than one hundredth of an acre, or 0.03 acre when extrapolated over a 1-mile distance. Plant communities along the edge of Ranch Creek include heartleaf bittercress-tall fringed bluebells-arrowleaf ragwort herbaceous vegetation, subalpine fir-Engelmann spruce/tall fringed bluebells forest, and subalpine fir-Engelmann spruce/thinleaf alder forest. Because of the small change to the 2-year flow, changes to these plant communities are likely to be confined to the edge of the stream and consist of shifts in vegetation composition. These changes are expected to be negligible.

There would be no changes in the 5- and 10-year flows compared to Current Conditions (2006) (Tables 4.6.8-3 and 4.6.8-4). The 5- and 10-year flow would be 101 and 126 cfs, respectively. The width of overbank flow would only be about 1 foot for the 5-year flow and 2.3 feet for the 10-year flow.

The Proposed Action combined with other RFFAs would have negligible or no effects to wetland and riparian functions.

Fraser River Tributaries

Under the Proposed Action with RFFAs, Denver Water would divert water from 33 tributaries of the Fraser River (Figure 3.0-2), including St. Louis Creek and Ranch Creek which are discussed as FR3 and FR4. Table 4.6.8-6 provides a summary of the Total Environmental Effects with the Proposed Action with RFFAs compared to Current Conditions (2006). The amount of water diverted would increase from all of these creeks, as a result of the Proposed Action with RFFAs, Full Use of the Existing System, and additional municipal and snow making diversions. A number of these streams have minimum bypass requirements (Table 3.1-8), while others that do not have minimum bypasses are already fully diverted at times during the year (Denver Water 2009b). The two tributaries that were evaluated at sampling sites FR3 and FR4 both have minimum bypass flows. Most of the diversions would occur during high flows, which are represented in the table below by June data.

Table 4.6.8-6
Summary of Hydrological Changes for Fraser River Tributaries from Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Stream Type and Name	Appendix H Table with Flow Change Data	Flow Reduction in June/% Change	Dry Period (No Flow) Occurs Under Current Conditions (2006) (average days per year)	Increased Number of Days During Growing Season* with No Flow	Affected Length (miles)	Extent of Riparian Habitat below Diversion
Rosgen Type B/C Streams, with Bypass Requirements						
St. Louis Creek	H-1.40	-10.7 cfs / -27%	No	0	9.7	Extensive
Vasquez Creek	H-1.35	-23.1 cfs / -41%	No	0	3.0	Extensive
Main Ranch Creek	H-1.47	-4.5 cfs / -22%	No	0	10.6	Extensive

Table 4.6.8-6 (continued)
Summary of Hydrological Changes for Fraser River Tributaries from Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Stream Type and Name	Appendix H Table with Flow Change Data	Flow Reduction in June/% Change	Dry Period (No Flow) Occurs Under Current Conditions (2006) (average days per year)	Increased Number of Days During Growing Season* with No Flow	Affected Length (miles)	Extent of Riparian Habitat below Diversion
Rosgen Type B/C Streams, No Bypass Requirements						
Jim Creek	H-1.30	-5.5 cfs / -54%	Yes (345)	5	0.9	Extensive
Main Elk Creek	See Elk Creek and Tributaries				4.7	Extensive
West St. Louis	See St. Louis Creek Tributaries				2.4	Extensive
Rosgen Type A/Aa+ Streams, with Bypass Requirements						
Englewood Ranch Gravity System (Little Cabin, Cabin, Hamilton, Hurd, North and South Trail, Meadow)	H-1.45	-1.3 cfs / -2%	No	0	21.2	Patchy
Rosgen Type A/Aa+ Streams, No Bypass Requirements						
St. Louis Creek Tributaries - West St. Louis, Short, Iron, Byers, East St. Louis, Fool	H-1.41	-11.6 cfs / -43%	Yes (334)	13	2.0+ (does not include West St. Louis, listed above)	Limited (does not include West St. Louis, listed above)
King Creek	H-1.43	-0.5 cfs / -44%	Yes (342)	13	1.4	Limited
Elk Creek and Tributaries - West Elk, East Fork Main Elk, West Fork Main Elk, Main Elk, East Elk Creeks	H-1.39	-2.9 cfs / -38%	Yes (238)	6	3.8 (does not include Main Elk, listed above)	Limited except West Elk (does not include Main Elk, listed above)
Little Vasquez Creek	H-1.36	-4.4 cfs / -64%	Yes (343)	10	1.3	Limited
Cooper Creek	H-1.32	-0.4 cfs / -73%	Yes (291)	7	0.6	Very limited
Cub and Buck Creeks	H-1.31	-1.3 cfs / -58%	Yes (178)	7	1.1	Very limited
Middle and South Forks of Ranch Creek	H-1.48	-8.7 cfs / -35%	Yes (325)	13	4.7	Limited, patchy
North Fork Ranch and Dribble Creeks	H-1.46	-3.6 cfs / -23%	Yes (295)	9	1.3	Limited

Notes:
*The growing season is defined as April through September.
RFFA = reasonably foreseeable future action

All of the 6 Rosgen Type B/C streams have large wetland and riparian complexes on relatively wide valley floors downstream of the diversions. Fens are present on Vasquez Creek above and below the diversion, along Jim Creek and at West Elk Creek above the diversion. In addition, based on National Wetlands Inventory (NWI) maps, wetlands and riparian areas up to a quarter mile wide are present on some stream segments classified as Rosgen A/Aa+, on their flatter lower reaches, including King Creek, West Elk Creek, Little Vasquez Creek, and South Fork of Ranch Creek. NWI maps do not show any wetlands on the tributaries that occur in steep and narrow valleys, including Short, Byers, Iron, Fool, East St. Louis, East Elk Creek, East and West Forks of Elk Creek, Cooper Creek, Cub, Buck, and Dribble Creek. Large herbaceous and/or shrub wetlands are present on some streams that have wide valleys some distance above the diversions but not near or below the diversions, including Middle Fork Ranch and North Fork Ranch.

Field observations in September and October 2010 above and below 19 of the 27 diversion sites on Rosgen A/A+ streams found that riparian vegetation was variable but generally limited in area. Some sites had subalpine forest to the stream bank, with little or no riparian or wetland vegetation, including West St. Louis (except for a small fen described below), Short Creek, Byers Creek above the diversion, Iron Creek above the diversion, East St. Louis below the diversion, and Little Vasquez above the diversion. More often, the streams were bordered by subalpine forest with a narrow and often discontinuous strip of alder and/or Drummond's willow and mesic herbs; tributaries with these characteristics included Iron Creek below the diversion, Byers Creek below the diversion, East St. Louis, Fool, West Elk, East Elk, Little Vasquez below the diversion, Buck Creek, Middle Fork of Ranch Creek, and North Fork of Ranch Creek. Diversions are often located where there is a change in topography, and some sites exhibit differences above and below the diversions that appear to be related to steepness of slope. The existing diversions did not appear to be causing differences between upstream and downstream riparian habitat at most sites. Two sites have herbaceous wetlands, including West Elk Creek which has a small fen just above the diversion, and Cub Creek which has a wet meadow below the diversion. Shrub riparian dominated by alder and willow was present at Buck Creek, Cub Creek, and the South Fork of Ranch Creek, and at several streams on the Englewood Ranch Creek Extension that have minimum bypass flows. Groundwater seepage was observed at some of the sites, including West St. Louis, Cub Creek, and North Fork of Ranch Creek. Wetlands generally occurred only at sites where groundwater seepage was observed.

In a recent master's thesis, streams in the Fraser River watershed were studied (McCarthy 2008) to evaluate aquatic habitat and recovery downstream of the existing Denver Water diversions structures. That report indicated there were 18 streams where diversion structures were removing nearly all of the stream flow. At 9 of these 18 locations, flow recovered downstream of the diversion structures. At the 9 diversions in which stream flows recovered downstream, McCarthy (2008) states: "Downstream of diversion structures, flow recovery was evident at all sampled reaches via groundwater recharge within 0.41 kilometer or less of the diversion structure. This influx to the stream reaches is most likely the resurfacing of shallow groundwater or hyporheic flows from the impounded area upstream of the diversion structure. However, influx to the stream reaches could also be contributed from saturated topsoil, deeper groundwater seepage points, or alluvial valley bottom storage." McCarthy (2008) also notes that in some areas below the diversions, tributaries and wetlands contribute more water to stream flow than groundwater. McCarthy also states: "It is also important to note that these results reflect a subset of streams that are able to maintain discharge from initial recovery point to confluence with a larger stream. In the summer of 2006, nine of the streams in the Fraser River Basin that were 100% diverted showed no recovery and either consisted of a series of unconnected pools or were completely dry along the entire channel to the confluence."

There would be two types of changes to hydrology that could affect wetland and riparian habitats: (1) reducing the amount of flow during spring runoff at all diversions, and (2) extending the season with no surface flow at some of the diversions. Flows and diversions occur primarily during snowmelt in May, June, and July. Flows in most of the tributaries would be reduced 20-75% in June, the month of highest runoff. Impacts to riparian areas along the larger streams and those with bypass flows would be generally similar to those described for sampling sites FR3 and FR4. The large valley wetlands along the Rosgen B/C streams are probably maintained by a mix of surface and groundwater, and groundwater discharge is evident at some sites that were visited including lower St. Louis Creek, Jim Creek, and Vasquez Creek. Reductions of flows could have localized effects on groundwater, but discharge of groundwater from adjacent uplands would remain unchanged. Impacts to riparian areas along the Rosgen A/Aa streams would be minor because of the limited occurrence of riparian habitats. Although the high flows associated with snowmelt would be reduced, there would continue to be seasonally high flows during snowmelt. Reductions in seasonally high flows during snowmelt would reduce the availability of water during the growing season, and may result in a gradual reduction in the amount of species such as alder and Drummond's willow.

There are 21 streams without bypass requirements where current diversions already capture most of the natural flow for large portions of the year. Increased diversions would mostly occur during the runoff season and would not increase the length of the dry period in most years. Increased diversions would only occur in the winter during two wet years during the study period, at a time when the tributaries are normally dry. The other 43 years would remain unchanged. At streams that do have bypass requirements, the reductions in June and average monthly flow would be less, and there would be no months without flow in the streams.

Fraser Valley Fens

Fens were observed near the diversions at several locations on the Fraser River tributaries, and are likely to occur at additional sites. Tributaries where they were observed include Jim Creek, Vasquez Creek, and West St. Louis Creek. The fens along Jim Creek and West St. Louis Creek were elevated above the stream and appear to be entirely supported by groundwater discharge. The fen at Vasquez Creek extended across much of the valley bottom except adjacent to the stream channel where mineral soils were present. The portion of the fen away from the river was saturated in September 2010, but the areas nearer the channel were not. This suggests that the primary source of hydrology is groundwater. Stream flow including seasonal high flows could contribute to alluvial groundwater along the banks but would be peripheral to the fen. Because the primary source of hydrology for fens is regional groundwater, the Proposed Action with RFFAs would have no or negligible effect to fens and would not contribute to cumulative impacts to fens. Fens are not created or sustained by bank storage.

Williams Fork River

Sampling Site WF2

Two sampling sites were established on the upper portion of the Williams Fork River. Based on the PACSM output for the Williams Fork below Steelman gage (Table H-1.56), flows would be diminished by 21% in June at the upper site (WF2), from 88 cfs to 69 cfs. Decreased flow would occur in almost every month on average, but additional diversions in winter months from late summer through early spring would be minimal except during infrequent very wet years. The 2-year flow would decrease from 205 cfs to 202 cfs at WF2 (Table 4.6.8-1). Durations of flows of about 40 cfs or less would remain very similar to Current Conditions (2006) at WF2 (Appendix H-9).

The stream elevation of the 2-year flow would drop by approximately 0.2 inch (Table 4.6.8-2). This represents about a one inch reduction in wetted width on each side of the channel, about 0.5% of stream width for the 2-year flow under Current Conditions (2006). Expressed as an area, the reduction over the 590-foot study segment would be approximately 0.002 acre, or 0.02 acre when extrapolated over a 1-mile distance, a negligible effect. The one-inch reduction in wetted width for the 2-year flow would primarily occur in the narrow areas along the stream edge, in heartleaf bittercress-tall fringed bluebells-arrowleaf ragwort herbaceous vegetation and subalpine fir-Engelmann spruce/Drummond's willow forest. It would not affect the bog birch/mesic forb-mesic graminoid community, which is located above the 2-year flow.

There would be no changes in the 5- and 10-year flows compared to Current Conditions (2006) (Tables 4.6.8-3 and 4.6.8-4). The 5- and 10-year flows would be 276 and 292 cfs, respectively.

The Proposed Action combined with other RFFAs would have no effect on the fen that extends to the edge of the Williams Fork in the southwest portion of the sampling site, because the fen is topographically higher than the river at bankfull. The small reduction in 2-year flow would not affect the sources of hydrology for the fen.

The Proposed Action combined with other RFFAs would have moderate effects on wetland/riparian function, support of fish/aquatic habitat, and minor effects to several other functions, including flood attenuation, short- and long-term water storage, and production export/food chain support. Impacts to other functions would be negligible. (Note: this analysis addresses only wetland function; impacts to the fish and aquatic biological resources habitat are evaluated in Section 4.6.11.)

Sampling Site WF1

At the Williams Fork River near Sugarloaf Campground site, the stream elevation of the 2-year flow would not change from Current Conditions (2006) (Table 4.6.8-2), and there would be no effects to riparian or wetland areas. There would also be no changes in the 5- and 10-year flows (Tables 4.6.8-3 and 4.6.8-4). Implementation of the Proposed Action with RFFAS would therefore have no effects to wetland and riparian functions at this location.

Williams Fork Tributaries

Other RFFAs combined with the Proposed Action would include increased diversions from four tributaries of the Williams Fork (Table 4.6.8-7). As with the Fraser River tributaries, diversions from tributaries of the Williams Fork include two types of changes to hydrology that could affect wetland and riparian habitats – they would reduce the amount of flow during spring runoff at all diversions and would extend the season with no surface flow at some of the diversions. Flows and diversions occur primarily during snowmelt in June and July. Flows in tributaries would be reduced 20-30% in June, the month of highest runoff. The pattern of seasonally high stream flow during snowmelt would continue, but the amounts would be reduced. The Proposed Action with RFFAs would also extend the period without flow, primarily in the late fall. Steelman and Bobtail creeks are Rosgen Type A streams, and Jones and McQueary are Rosgen Type Aa+ streams. NWI maps show that the Steelman Creek Diversion is located within a valley wetland/riparian complex (PSS/PEM) while the others do not have mapped wetlands or riparian below the diversion, except a very small area on Bobtail Creek. Wetland/riparian areas are present upstream in flat valley bottoms on Steelman, Bobtail, and McQueary creeks.

Table 4.6.8-7
Summary of Hydrological Changes for Williams Fork Tributaries, Total Environmental Effects with the Proposed Action with RFFAs (2032) Compared to Current Conditions (2006)

Stream Name	Appendix H Table with Flow Change Data	Flow Reduction in June/% Change	Dry Period (No Flow) Occurs under Current Conditions (2006) (average days per year)	Increased Number of Days During Growing Season* with No Flow	Affected Length (miles)
Steelman Creek	H-1.52	-4.2 cfs / -22%	Yes (313)	22	1.9
Bobtail Creek	H-1.53	-8.4 cfs / -24%	Yes (316)	21	1.6
Jones Creek	H-1.54	-2.0 cfs / -19%	Yes (311)	23	0.2
McQueary Creek	H-1.55	-3.6 cfs / -28%	Yes (318)	20	0.4

Notes:
*The growing season is defined as April through September.
RFFA = reasonably foreseeable future action

The increased diversions on the Williams Fork tributaries would have flow reductions in June similar to those at sampling sites FR3, FR4, and WF2. Similar to those sites, cumulative impacts to riparian areas from reductions in high flows are expected to be negligible to minor.

Colorado River

One sampling site (CR1) was established to represent conditions on the Colorado River segment and was located between the towns of Parshall and Hot Sulphur Springs. Based on the PACSM output for the Colorado River below Windy Gap diversion (Table H-1.58), reductions in flow would mostly occur from April through August and would be about 19% in June. The 2-year flow would be reduced from 826 cfs to 610 cfs at CR1 (Table 4.6.8-1). Durations of flows of 500 cfs or less would remain similar to Current Conditions (2006) at CR1 (Appendix H-9).

The change in stream elevation associated with a 2-year event on this segment would be about 3.5 inches, and the change in river width would be about 2.4 feet, a reduction of less than 2% compared to Current Conditions (2006) (Table 4.6.8-2). The reduction in inundated area would be 0.05 acre within the 953-foot study segment, or 0.3 acre when extrapolated over a 1-mile distance. The change in wetted width would primarily affect reed canarygrass herbaceous vegetation, which occurs at and below the bankfull elevation. This is an aggressive non-native species which can grow under both hydric and mesic conditions and is not likely to be adversely affected by small changes in stream flow. The beaked sedge herbaceous vegetation occurs lower on the banks and would not be affected by changes in the 2-year flow. Although the vegetation may show little effect, impacts from changes in the 2-year flow were rated as minor because of effects on riparian habitat.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. The 5-year flow would be reduced from 2,696 cfs at Current Conditions (2006) to 2,235 cfs, and the 10-year flow would be reduced from 3,490 cfs to 3,294 cfs. Reduction due to changes in the 5-year flow would be about 5 inches in height and about 5.5 feet in width, a reduction of about 3% of stream width under Current Conditions. Reductions due to changes in the 10-year flow would be about 1.5 inches in height and about 1.25 feet in width. The small amount of reductions in the 5- and 10-year flows would primarily affect thinleaf alder-mixed willow shrubland. The average width of overbank flooding would be about 37 feet for the 5-year flow and 46 feet for the 10-year flow, similar to the area of overbank flooding under Current Conditions (40 and 45 feet, respectively). Overbank flooding would affect about 34% of the riparian area for the 5-year flow and 41% for the 10-year flow. Changes in the 5- and 10-year flows could have minor cumulative effects on riparian habitats.

Changes in flows would have little or no effect on wetlands or hay meadows away from the edge of the Colorado River. These wetlands are maintained primarily by groundwater and/or irrigation practices. Along this river segment, groundwater flows toward and into the river, with the level of the water table naturally supported by infiltration of precipitation and snowmelt in areas directly upgradient (uphill) from the river, as well as percolation of water through streambeds where the surface water level is above the groundwater level. Local exceptions to this pattern exist where irrigation well pumping causes drawdown of the water table surrounding the pumping wells, and where irrigation water pumped from the river and applied to hay meadows also recharges the water table. Drought conditions such as in 2002 and prior years will also reduce groundwater levels throughout the region because there is much less recharge to the groundwater flow system during dry years.

Because overbank flooding in longer-term floods would be similar to Current Conditions, reductions in flows would have negligible or minor effects on cottonwood establishment. In the western U.S., cottonwood populations along rivers are linked to stream hydrology (Lytle and Merritt 2004). Flood flows provide moist bare mineral soils needed for seedling establishment. Cottonwood stands that develop on newly created sites along the edges of rivers eventually form late successional forests on older and higher terraces, unless they are removed by channel meandering, drought or other causes.

Changes in flow at this sampling site would result in negligible to minor cumulative effects to wetland and riparian habitat including changes in composition to more mesic species in areas adjacent to the stream. RFFAs combined with the Proposed Action would have minor cumulative effects to several wetland and riparian functions, including support of fish/aquatic habitat, flood attenuation, and short- and long-term water storage. Impacts to other functions would be negligible. The existing riparian vegetation provides minimal shading of the stream and this would not change.

Blue River

The 1.33-acre Representative sampling site (BR1) is located along the Blue River midway between Dillon Reservoir and Green Mountain Reservoir. Based on the PACSM output for Dillon Reservoir Outflow (Table H-1.63), average stream flows would be reduced 33% in June, from 769 cfs to 516 cfs. The volume of the 2-year flow would be reduced from 1,910 cfs to 1,358 cfs at BR1 (Table 4.6.8-1). Durations of flows of about 400 cfs or less would remain similar to Current Conditions (2006) at BR1 (Appendix H-9).

The change in stream elevation associated with a 2-year flow event at this location would be about 14 inches (Table 4.6.8-2). The width of the stream would be reduced by about 10 feet, a reduction of about 9% of the stream width under Current Conditions (2006). Over a distance of 1,000 feet, this translates to a reduction in inundated area of approximately 0.23 acre, or 1.2 acres when projected over a 1-mile distance.

The width of the area of reduced inundation would be approximately 5 feet on each side of the channel. The plant community that is located within the zone of reduced inundation is thinleaf alder-mixed willow shrubland, which occurs as a narrow strip on each side of the river, restricted by topography. On the right (north) side of the river the shrubs are bounded by a steep slope that rises about 25 feet to the valley bottom. On the left bank the strip of dense shrub is bordered by a steep slope and a terrace with groundwater wetlands. Alders, willows and herbaceous wetland vegetation are likely to expand into the portions of the stream channel that are no longer affected by the 2-year flow. The upper part of the streamside alders and willows may gradually move down slope in response to reductions in the 2-year flow, because the width of impact is large enough to affect individual shrubs. It may also not change, because hydrology for the streamside shrubs appears to be provided both from the river and from groundwater wetlands on a terrace above the channel on the south side.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. The 5-year flow would be reduced from 2,335 cfs at Current Conditions (2006) to 2,282 cfs, and the 10-year flow would be reduced from 2,430 cfs to 2,402 cfs. Reductions due to changes in the 5-year flow would be about 7 inches in height and about 4 feet in width. Reductions due to changes in the 10-year flow would be about 7 inches in height and about 3.7 feet in width. The small amount of reductions in the 5- and 10-year flows would primarily affect thinleaf alder-mixed willow shrubland. The average width of overbank flooding would be about 9 feet for the 5-year flow and 10 feet for the 10-year flow, larger than the area of overbank flooding under Current Conditions (3 and 3.5 feet, respectively). Overbank flooding would affect about 14% of the riparian area for the 5-year flow and 15% for the 10-year flow. The wetlands that occur on the terrace south of the stream are above the elevations affected by 5- and 10-year flows. They are supported by groundwater and surface runoff and would not be affected by changes in stream flow. These include the blue spruce – thinleaf alder woodland and beaked sedge communities that comprise most of the wetland and riparian vegetation at this sampling site.

Although this site would exhibit greater reductions in the 2-year flow elevation and width than the other study sites, the effect on wetland and riparian vegetation would be minor because of site factors including groundwater discharge and steep slopes adjacent to the stream that would limit the amount of vegetation that would be affected. However, impacts might be moderate at other areas along the Blue River. Changes in the 5- and 10-year flows could have minor effects on riparian habitats.

At this sampling site, implementation of the Proposed Action combined with RFFAs would have moderate cumulative effects to several wetland and riparian functions, including support of fish/aquatic habitat, flood attenuation, and short- and long-term water storage, and minor impacts to nutrient/toxicant removal. Most of the changes in function would result from the RFFAs. The amount of shading of the stream is not likely to change. The Proposed Action with RFFAs is expected to have no effects on flood attenuation or short- and long-term water storage at this sampling site.

South Boulder Creek

Sampling Site SBC1

In the segment above Gross Reservoir (sampling site SBC1), flows would increase by 20% in June, from 606 cfs to 726 cfs, with similar or lesser increases in several other summer months, based on the PACSM output for South Boulder Creek at Pinecliffe gage (Table H-1.65). These flows are within the normal range of variability. For example, the average monthly flow in June is forecasted to be 726 cfs with implementation of the Project with RFFAs, but flows in excess of 1,100 cfs already occur during wet years at the gage. The 2-year flow would increase from 852 cfs to 944 cfs at SBC1 (Table 4.6.8-1). There would be changes in durations of most flows above 100 cfs, compared to Current Conditions (2006) at SBC1 (Appendix H-9).

In terms of stage, the elevation of a 2-year event would increase by approximately 2 inches (Table 4.6.8-2). The width of the stream would be increased by about 1 foot, about 2% of the stream width under Current Conditions (2006). The area affected over the 559-foot reach would be 0.01 acre, or 0.1 acre when extrapolated over a 1-mile distance. Within the narrow zone influenced by this increase in stage, there may be a gradual increase in species better adapted to wetter conditions, such as beaked sedge, but the overall impact on riparian vegetation would be negligible. It is also possible that there would be a small increase in the area occupied by riparian vegetation or in the density of riparian vegetation due to the increase in inundated area associated with a 2-year event. The increased 2-year flow would primarily occur in the Drummond's willow/mesic forb shrubland.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. The 5-year flow would increase from 984 cfs under Current Conditions (2006) to 993 cfs, and the 10-year flow would increase from 1,003 cfs to 1,015 cfs. Increases due to changes in the 5-year flow would be about 0.2 inch in height and less than 0.1 foot in width. Changes due to changes in the 10-year flow would be about 0.3 inch in height and less than 0.1 foot in width. The area of overbank flooding from the 5- and 10-year flow would be very small (<1 foot) and would be similar to Current Conditions (2006). The increased amount of overbank flow would primarily occur in the Drummond's willow/mesic forb shrubland. These increases would have a negligible cumulative effect on riparian vegetation.

RFFAs combined with the Proposed Action would have negligible cumulative effects to wetland functions at this site.

Sampling Site SBC3

In the segment below Gross Reservoir and above the South Boulder Diversion Canal, flow would decrease from May through September, and would increase in other months, particularly December through February, based on the PACSM output for Gross Reservoir Outflow (Table H-1.66). The reduction in outflow in June would be 8%, from 434 cfs to 398 cfs. The 2-year flow would be reduced from 645 cfs to 574 cfs at SBC3 (Table 4.6.8-1). There would be changes in durations of most flows, compared to Current Conditions (2006) at SBC3 (Appendix H-9).

The change in stage associated with a 2-year flow event would be approximately a 2-inch drop in stream elevation (Table 4.6.8-2). The width of the stream would be reduced by about 4.7 feet, a reduction of about 7% of the stream width under Current Conditions (2006). The area affected over the 446-foot reach would be 0.05 acre, or about 0.6 acre when extrapolated over a 1-mile distance.

The width of the area of reduced inundation would be approximately 2.35 feet on each side of the channel. The streambanks in this sampling area are dominated by the river birch/mesic forb community, which is not likely to be adversely affected by a small change in stage. The herbaceous understory generally consists of species that are capable of adapting to somewhat drier conditions, such as bluejoint reedgrass. This community is likely to gradually colonize the gravel bars on the edge of the reduced channel, resulting in a wider zone of riparian vegetation. This increase in riparian vegetation would be a minor positive impact.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. The 5-year flow would be reduced from 741 cfs at Current Conditions (2006) to 687 cfs, and the 10-year flow would be reduced from 821 cfs to 737 cfs. Reductions due to changes in the 5-year flow would be about 1.4 inches in height and about 1.3 feet in width, about 2% of stream width. Reductions due to changes in the 10-year flow would be about 2 inches in height and about 2 feet in width. The area of overbank flooding would be fairly small, a total of about 6 feet in width for the 5-year flow and 7 feet for the 10-year flow. Reductions in the 5- and 10-year flows would likely occur in vegetation mapped as blue spruce/field horsetail woodland, river birch/mesic graminoid, and redtop herbaceous vegetation. These three communities extend above the area affected by 10-year flows and are probably associated with groundwater discharge or surface runoff. Cumulative impacts from change in the 5- and 10-year flows would be negligible.

Changes in flow at this sampling site would result in minor changes to wetland and riparian habitat including widening of the narrow strip of riparian vegetation adjacent to the stream. There would be negligible cumulative effects to wetland and riparian functions.

North Fork South Platte River

Sampling Site NF1

Two sampling sites were established in the segment (NF1 and NF2), both of which would experience a decrease in flows during the winter months and an increase in flows during the summer months.

Average monthly flows at the North Fork South Platte River below Geneva Creek gage would increase by approximately 40% during the period May through September, based on the PACSM results for North Fork South Platte River below Geneva Creek gage (Table H-1.68). The average June flow below the gage would increase from 312 cfs to 404 cfs. At NF1, the 2-year flow would increase from 540 cfs to 636 cfs (Table 4.6.8-1). There would be changes in durations of most flows at NF1, compared to Current Conditions (2006) (Appendix H-9). The increased summer flows would fall within the normal range of variability from year to year that already influences the stream system. The average monthly flow decrease at this location during the period November-March would range from about 10 to 20% (Table H-1.68). In the absence of an impact on groundwater levels, which is not expected due to an overall increase in flows, decreased flows in winter should not have any impact on riparian vegetation during its dormant period.

The increased stage from a 2-year event would be 2.5 inches (Table 4.6.8-2). The width of the 2-year flow would be increased by about 2 feet at Site NF1, an increase of about 3% of stream width under Current Conditions. The area affected over the study reaches would be 0.01 acre at Site NF1. Extrapolated over a 1-mile distance, the area affected would be 0.2 acre. Widening of the stream would remove a small amount of existing riparian vegetation, mostly in the narrowleaf cottonwood/red osier dogwood community, in which rose is the most abundant understory species, and in the river birch/mesic graminoid community. The area affected represents only small portion of the total width of existing riparian vegetation (Table 4.6.8-5). These cumulative impacts would be negligible.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. The 5-year flow would be increased from 638 cfs to 656 cfs. Increases due to changes in the 5-year flow would be about 2 inches in height and 2 feet in width. The 10-year flow would be increased from 645 cfs to 668 cfs. Increases due to changes in the 10-year flow would be about 0.5 inch in height and 0.5 feet in width at NF1. The area of overbank flooding would be very small, 0.5 to 1 foot for the 5- and 10-year flows. The area affected by changes in 5- and 10-year flows would be very small compared to the width of existing riparian vegetation, and these changes would have negligible cumulative effects.

Flow increases along the North Fork South Platte River would have negligible effects on wetland and riparian areas and functions. Implementation of the Proposed Action in combination with other RFFAs would have minor effects to several wetland and riparian functions, including support of fish/aquatic habitat, flood attenuation, short- and long-term water storage, and nutrient/toxicant removal. Cumulative impacts to other functions would be negligible.

Sampling Site NF2

Like NF1, this site would experience a decrease in flows during the winter months and an increase in flows during the summer months (Table H-1.68). The 2-year flow at NF2 would increase from 626 cfs to 683 cfs (Table 4.6.8-1). There would be changes in durations of most flows, compared to Current Conditions (2006) (Appendix H-9).

The increased stage from a 2-year event would be 1 inch at sampling site NF2 (Table 4.6.8-2). The width of the 2-year flow would be increased by about 0.3 feet (4 inches), an increase of less than 1% of stream width under Current Conditions (2006). The area affected would less than 0.01 acre within the sampling site, and would be less than 0.1 acre extrapolated over a 1-mile distance. Impacts would occur in the strapleaf and sandbar willow communities at NF2. These impacts would be negligible.

Changes in the 5- and 10-year flows are presented in Tables 4.6.8-3 and 4.6.8-4. The 5-year flow would be slightly increased from 762 cfs to 772 cfs at NF2, and there would be no change in the 10-year flow. Increases in the 5-year flow would be less than 1 inch in height and about 1 foot in width at NF2. These changes would have no effects on riparian vegetation.

Implementation of the Proposed Action in combination with RFFAs would have minor effects to several wetland and riparian functions, including support of fish/aquatic habitat, short- and long-term water storage, and nutrient/toxicant removal. Cumulative impacts to other functions would be negligible.

South Platte River

No sampling sites were located along the South Platte River between Antero Reservoir and the Henderson gage. Changes in flow during the growing season would be minimal in the upper South Platte River (Antero Reservoir to Cheesman Reservoir outflow, Tables H-1.69 and H-1.71). Flows would be reduced during the growing season at Waterton and below Chatfield Reservoir (Tables H-1.72 and H-1.73). Flows would be reduced by 12% in June at Waterton, from 515 to 455 cfs, and by a similar amount below Chatfield. There would be less change further downstream at the Denver and Henderson gages (Tables H-1.74 and H-1.75). Based on the results of HEC-RAS analysis at other sites, these changes are likely to have a minimal impact on stream elevation and inundated area during a 2-year event, and cumulative impacts on wetland and riparian habitats and functions would be negligible.

Summary of Total Environmental Effects at River Sampling Sites

Comparing Tables 4.6.8-2, 4.6.8-3, and 4.6.8-4 to similar tables for the Moffat Project alternatives (Table 5.8-4, 5.8-5, and 5.8-6), it can be seen that a large portion of the total environmental effects in the Fraser Valley (sites FR1, FR2, FR3, and FR4) and on South Boulder Creek would be caused by the Proposed Action with RFFAs. Most of the cumulative changes to flows in the Colorado and Blue rivers would occur from other actions including Full Use of the Existing System and local growth in water use. Full use of the Existing System would also contribute to cumulative effects to the Fraser River and its tributaries.

The area covered by 2-year flows would decrease in the Fraser River and its tributaries, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir; and would increase in South Boulder Creek above Gross Reservoir and North Fork South Platte River, compared to Current Conditions (2006). Changes would be largest along the Blue River (BR1) where the 2-year flow would be reduced by about 14 inches in depth and 10 feet in width. Changes are considered minor at the two mainstem Fraser River sampling sites (FR1 and FR2), Colorado River (CR1), and South Boulder Creek below Gross Reservoir (SBC3), and negligible at the other sites except WF1 which would have no changes in the 2-year flow.

Decreases in the 2-year flow could result in a gradual narrowing of the stream banks, which would decrease hydrology for wetlands within the banks. However, sediment deposition may be temporary and may be removed by longer-term floods. Impacts would be confined to a wetland fringe where it currently exists along the edge of the channel. In the long run, the wetland may relocate to the new edge of channel. Herbaceous wetland vegetation affected by less frequent or prolonged flooding would likely change in composition and become more mesic. The affected area would be relatively narrow and is not likely to lead to the death of shrubs or trees. Where narrowing occurs, vegetation would respond by gradually adjusting its location, moving downgradient to remain in the same hydrological zone. Changes are likely to be very slow in most areas because the reductions in the 2-year flow would be relatively small compared to the rooting zone of most of the affected vegetation (willow and alder shrubs). Thus an individual shrub might have reduced water in a portion of its rooting zone but may not show a visible response because most of its rooting zone is not affected. Herbaceous vegetation is likely to respond faster. The zone of reduced hydrology is likely to show a change in composition to riparian species with somewhat lower water requirements, or upland species such as conifers. Vegetation would respond similarly to increases in flow at SBC1, NF1, and NF2, with small gradual upward shifts in wetland vegetation.

The area of overbank flooding resulting from the 5- and 10-year flows would decrease in the Fraser River, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir and would have little change at the other sites. For affected sites, cumulative flow changes would generally reduce the stream stage by 1 to 7 inches in height, width of inundation by 2 to 6 feet in width, and area of inundation by 0.1 to 0.8 acre/mile for the 5- and 10-year flows. Reduction in overbank flow would reduce hydrology that supports bank and overbank vegetation, and groundwater recharge. These changes could reduce riparian vegetation density or productivity and cause changes in composition including increases in upland species. Changes in 5- and 10-year flows would result in minor cumulative effects to riparian habitat on the Fraser River (FR1 and FR2), Colorado River (CR1), Blue River (BR1), and South Boulder Creek below Gross Reservoir (SBC3), and negligible to no cumulative effects at other sites.

Changes in the width of the 5- and 10-year flows would be generally similar in size and would affect relatively narrow areas along the banks. Although shown as an average width in the tables, the actual width would be variable based on the local microtopography and flooding patterns. The total width of inundation associated with the 5- and 10-year flows shown in Tables 4.6.8-3 and 4.6.8-4 are not substantially larger than for the 2-year flow. In the larger valleys such as the lower Fraser River, Colorado River, Blue River, and North Fork, the width of the valley floor is typically much larger than the width inundated under the 5- and 10-year flow and results in part from historic movements of the channel during floods. Historic reductions in peak flows reduce channel movement and may affect recruitment of cottonwoods, which germinate after floods on wet bare mineral soil.

In addition to stream flow, wetlands and riparian areas along the stream segments are supported by groundwater. Reductions in stream flows would have very limited effects on groundwater, and would be restricted to localized areas immediately below the diversion and adjacent to the creeks. Discharge of groundwater that originates as snowmelt or hillslope runoff would continue. All of the streams flow through mountainous terrain and are expected to be gaining streams along much of their length. Several of the sampling sites have evidence of groundwater discharge and groundwater-supported wetlands, including FR1, FR2, FR3, WF1, WF2, and BR1. Information on the relative contributions of groundwater and surface water is not available. However, the width of riparian vegetation is often much wider than the area affected by 5- and 10-year flows, suggesting a large contribution from groundwater. In addition, wetlands are often located near the edge of the valley or on terraces above the rivers.

Most of the reasonably foreseeable future water projects described in Section 5.3.1 would have limited new effects on the river reaches in the Moffat Project area. Exceptions include the Windy Gap Firming Project and urban growth in Grand and Summit counties. Direct losses of wetlands in Grand and Summit counties due to growth would be limited because of requirements for Section 404 permitting and mitigation, but indirect impacts could occur from changes in land use and irrigation practices. Although some cumulative losses of wetlands and riparian could occur from indirect effects, it is unlikely that there would be major or even moderate cumulative changes in riparian and wetlands areas along East Slope or West Slope streams in the analysis area from future water projects.

Climate change could have adverse effects on wetlands and riparian areas in both the mountains and Front Range areas. Reduced runoff, changes in season of runoff, and increased evapotranspiration during a longer and warmer growing season is likely to reduce the distribution and seasonal availability of surface water and soil moisture, resulting in smaller wetlands and riparian areas, reductions in quality, and changes in plant species composition. The amount and importance of these impacts are unknown at the current time. The Moffat Project would make a minimal contribution to these cumulative impacts.

Tree deaths from mountain pine beetle are not likely to adversely affect riparian areas, but would affect runoff timing and volume. Lodgepole pine, the principal species that is being affected by mountain pine beetle in Grand County, is an upland species not dependent on stream flows, floods or groundwater. The death of large numbers of adult lodgepole pine changes forest structure and habitat conditions and has effects on watershed hydrology. It decreases overhead shading and increases the cover and production of groundcover and understory species, which are suppressed in the dense shade of even-aged lodgepole pine forests. Fire hazards increase while trees are in the red foliage stage, decreases when the needles fall, and increases again when the trees begin falling (Colorado State Forest Service 2009). Reduced tree cover generally results in an increase in runoff volume, earlier runoff, and increased soil moisture because of reduced snow interception in the winter and decreased evaporation in the summer (MacDonald et al. 2003; Hélie et al. 2005). Runoff would decrease again as the forest regrows, and water yield will return to their pre-disturbance state in about 60 years in subalpine areas. Decrease in forest cover from beetle kill will have little effect on the timing or amount of runoff in lower elevation areas that have less than about 20 inches of precipitation. The increase in ground vegetation helps prevent erosion, and forests affected by mountain pine beetles do not typically have adverse effects to water quality.

The reduction in overstory shading is likely to promote growth of riparian species such as alders, willows, and herbaceous species. Similarly, increased growth of understory and ground vegetation within the dying forests could reduce erosion and movement of sediment toward streams and riparian areas, because lodgepole pine forest often has a minimal understory due to dense shade. In the event of a fire, erosion and sediment transport would experience significant increases until revegetation occurs. Increased deposition of sediment within riparian areas would probably not adversely affect riparian vegetation in the long term because riparian areas are adaptable to this type of stress. Pulses of flow that remove or destroy riparian vegetation through erosion could cause long-term damage, but riparian areas would likely recover faster than upland areas because of adaptation to disturbance and higher availability of moisture for growth.

4.6.8.2 Alternative 1c with Reasonably Foreseeable Future Actions

Impacts under Alternative 1c would be the similar to those described for the Proposed Action with RFFAs. The expanded Gross Reservoir would be smaller (40,700 acre-feet [AF]) and would have direct and permanent impacts to 1.6 acres of wetlands, 3.2 acres of riparian habitat, and 5,118 feet of perennial streams.

Past actions that have affected wetlands and riparian vegetation in the Leyden Gulch Reservoir study area include construction of the existing Ralston Reservoir and other reservoirs, installation of culverts at road and railroad crossings, and changes in drainage patterns related to roads, railroads and other developments. Alternative 1c would result in direct and permanent impact to and 4.55 acres of wetlands and 1,255 feet of stream at the Leyden Gulch Reservoir site. The Leyden Gulch Reservoir site is within the expected growth corridor of the northwest Denver Metropolitan area. Although development may affect wetlands and riparian areas, the area and functions would remain similar to existing conditions because of permitting and mitigation requirements under Section 404.

For the river segments, total environmental effects with Alternative 1c (Table 4.6.8-8) would be very similar to those described for the total environmental effects with the Proposed Action with RFFAs. As shown by comparing the last two columns, the largest differences would be at Site SBC3, where Total Effects with Alternative 1c would be less than with the Proposed Action with RFFAs. Impacts to wetland and riparian areas would be minor along the Fraser River, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir, and would be negligible or none at the other sites.

Table 4.6.8-8
Two-, Five-, and 10-Year Flow Changes for Sampling Sites, Total Environmental Effects with Alternative 1c with RFFAs (2032) Compared to Current Conditions (2006)*

Sampling Site	Average Channel Width at Current Conditions (feet)	Total Environmental Effects for Alternative 1c Compared to Current Conditions (2006)			Proposed Action with RFFAs Area of Flow Change (acres per mile)
		Flow Elevation Change (inches)	Flow Width Change (feet)**	Area of Flow Change (acres per mile)	
2-Year Flows					
FR3	46.87	-1.99	-1.91	-0.23	-0.24
SBC3	70.26	-1.12	-3.97	-0.48	-0.57
5-Year Flows					
FR1	38.16	-3.35	-3.86	-0.47	-0.51
CR1	181.64	-4.77	-5.42	-0.66	-0.69
SBC3	72.71	+0.27	+0.25	+0.03	-0.16
10-Year Flows					
FR1	42.75	-4.33	-4.20	-0.51	-0.57
SBC3	74.68	+0.01	+0.04	0.00	-0.25

Notes:
*Results are only shown for sampling sites that differ from the results provided in Tables 4.6.8-2 through 4.6.8-4.
**Change of width includes both sides of river.
RFFA = reasonably foreseeable future action

4.6.8.3 Alternative 8a with Reasonably Foreseeable Future Actions

Impacts under Alternative 8a would be the similar to those described for the Proposed Action with RFFAs. The expanded Gross Reservoir would be smaller (52,000 AF) and would have direct and permanent impacts to 1.75 acres of wetlands, 3.6 acres of riparian habitat, and 6,195 feet of perennial streams.

Cumulative effects are also unlikely for resources at the South Platte River Facilities or Conduit O, because Project-related activities would have only minor and temporary impacts under the various alternatives. Although continued population growth and development along the Front Range could potentially affect these same areas, there would be minimal cumulative loss of wetlands.

For the river segments, total environmental effects with Alternative 8a (Table 4.6.8-9) would be very similar to those described for total environmental effects with the Proposed Action with RFFAs. Impacts to wetland and riparian areas would be minor along the Fraser River, St. Louis Creek, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir, and would be negligible or none at the other sites.

Table 4.6.8-9
Two-, Five-, and 10-Year Flow Changes for Sampling Sites, Total Environmental Effects with Alternatives 8a and 10a with RFFAs (2032) Compared to Current Conditions (2006)*

Sampling Site	Average Channel Width Flow at Current Conditions (feet)	Total Environmental Effects for Alternatives 8a and 10a Compared to Current Conditions (2006)			Proposed Action with RFFAs Area of Flow Change (acres per mile)
		Flow Elevation Change (inches)	Flow Width Change (feet)**	Area of Flow Change (acres per mile)	
2-Year Flows					
FR1	29.30	-7.58	-3.60	-0.44	-0.50
FR3	46.87	-1.79	-1.67	-0.20	-0.24
FR4	20.10	-0.80	-0.20	-0.02	-0.03
5-Year Flows					
FR1	38.16	-3.42	-3.95	-0.48	-0.51
SBC3	72.71	-1.31	-1.29	-0.16	-0.16
10-Year Flows					
FR1	42.75	-4.95	-4.70	-0.57	-0.57
CR1	186.54	-1.23	-0.84	-0.10	-0.15
SBC3	74.68	-2.13	-2.11	-0.26	-0.25

Notes:
*Results are only shown for sampling sites that differ from the results provided in Tables 4.6.8-2 through 4.6.8-4. Data shown are for Alternative 8a. Alternative 10a is similar.
**Change of width includes both sides of river.
RFFA = reasonably foreseeable future action

4.6.8.4 Alternative 10a with Reasonably Foreseeable Future Actions

Total environmental effects to riparian and wetland areas at Gross Reservoir under Alternative 10a would be the same as those described for Alternative 8a.

Cumulative effects are also unlikely for these resources at the Denver Basin Aquifer Facilities or Conduit M, because Project-related activities would have only minor and temporary impacts under the various alternatives. Although continued population growth and development along the Front Range could potentially affect these same areas, there would be minimal cumulative loss of wetlands.

For the river segments, total environmental effects with Alternative 10a (Table 4.6.8-9) would be very similar to those described for total environmental effects with the Proposed Action with RFFAs. Impacts to wetland and riparian areas would be minor along the Fraser River, St. Louis Creek, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir, and would be negligible at the other sites.

4.6.8.5 Alternative 13a with Reasonably Foreseeable Future Actions

Impacts under Alternative 13a would be the similar to those described for the Proposed Action with RFFAs. The expanded Gross Reservoir would be smaller and would have direct and permanent impacts to 1.8 acres of wetlands, 3.9 acres of riparian habitat, and 6,400 feet of perennial streams.

Cumulative effects are also unlikely for resources at the South Platte River Facilities or Conduit O, because Project-related activities would have only minor and temporary impacts under the various alternatives. Although continued population growth and development along the Front Range could potentially affect these same areas, there would be minimal cumulative loss of wetlands. On the other hand, agricultural water rights transfers under Alternative 13a are likely to result in moderate to major cumulative losses of wetlands and riparian habitats along the Front Range. Losses of wetlands and riparian areas would occur from removal of irrigation and ditch flows under Alternative 13a and from other water projects, as well as from continued development and urbanization of rural and semi-rural areas along the Front Range.

For the river segments, total environmental effects under Alternative 13a (Table 4.6.8-10) would be very similar to those described for the Proposed Action with RFFAs. Impacts to wetland and riparian areas would be minor along the Fraser River, St. Louis Creek, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir, and would be negligible for none at the other sites.

Table 4.6.8-10
Two-, Five-, and 10-Year Flow Changes for Sampling Sites,
Total Environmental Effects with Alternative 13a with RFFAs (2032)
Compared to Current Conditions (2006)

Sampling Site	Average Channel Width Current Conditions (feet)	Total Environmental Effects for Alternative 13a Compared to Current Conditions (2006)			Proposed Action with RFFAs Area of Flow Change (acres per mile)
		Flow Elevation Change (inches)	Flow Width Change (feet)**	Area of Flow Change (acres per mile)	
2-Year Flows					
FR1	29.30	-7.58	-3.60	-0.44	-0.50
FR3	46.87	-1.79	-1.67	-0.20	-0.24
FR4	20.10	-0.80	-0.20	-0.02	-0.03
5-Year Flows					
FR1	36.16	-3.42	-3.95	-0.48	-0.51
10-Year Flows					
CR1	186.54	-1.50	-1.05	-0.13	-0.15
SBC3	74.68	-1.89	-1.86	-0.23	-0.25

Notes:
*Results are only shown for sampling sites that differ from the results provided in Tables 4.6.8-2 through 4.6.8-4.
**Change of width includes both sides of river.
RFFA = reasonably foreseeable future action

4.6.8.6 No Action Alternative with Reasonably Foreseeable Future Actions

The No Action Alternative would have negligible direct permanent impacts to wetlands, other waters of the U.S., or riparian habitats than presently occur. Other than along the river segments, it would not have additional cumulative effects.

With this alternative, Denver Water would continue to operate their existing system under a higher demand. In addition, the No Action Alternative would result in depletion of the 30,000 AF Strategic Water Reserve at times and more frequent mandatory restrictions on use during droughts. A comparison of modeled changes in 2-, 5-, and 10-year flows that would result from total environmental effects with the No Action compared to Current Conditions (2006) is provided in Table 4.6.8-11. For the 2-year flows, hydrologic impacts would be greater in the Blue River Basin but less than or the same as the action alternatives at all other sites. Five-year flows would be about the same, and 10-year flows would be the same or less. Impacts to riparian vegetation would be similar to or less than described for the Proposed Action with RFFAs. Impacts to wetland and riparian areas would be minor along the Fraser River near Winter Park, Colorado River, and Blue River, and would be negligible at the other sites.

Table 4.6.8-11
Two-, Five-, and 10-Year Flow Changes for Sampling Sites, Total Environmental Effects with No Action Alternative with RFFAs (2032) Compared to Current Conditions (2006)*

Sampling Site	Average Channel Width Current Conditions (feet)	Total Environmental Effects for No Action Alternative Compared to Current Conditions (2006)			Proposed Action with RFFAs Area of Flow Change (acres per mile)
		Flow Elevation Change (inches)	Flow Width Change (feet)**	Area of Flow Change (acres per mile)	
2-Year Flows					
FR1	29.30	-3.29	-1.87	-0.23	-0.50
FR2	85.08	-0.69	-1.32	-0.16	-0.77
FR3	46.87	+0.02	+0.63	+0.08	-0.24
FR4	20.10	0.00	0.00	0.00	-0.03
WF2	29.97	0.00	0.00	0.00	-0.02
CR1	141.44	-3.51	02.40	-0.05	-0.29
BR1	108.89	-17.09	-12.65	-1.53	-1.23
SBC1	45.82	+0.90	+0.41	+0.05	+0.11
SBC3	70.26	+0.77	+0.75	+0.09	-0.57
NF2	64.30	+0.98	+0.22	+0.03	+0.04

Table 4.6.8-11 (continued)
Two-, Five-, and 10-Year Flow Changes for Sampling Sites, Total Environmental Effects with No Action Alternative with RFFAs (2032) Compared to Current Conditions (2006)*

Sampling Site	Average Channel Width Current Conditions (feet)	Total Environmental Effects for No Action Alternative Compared to Current Conditions (2006)			Proposed Action with RFFAs Area of Flow Change (acres per mile)
		Flow Elevation Change (inches)	Flow Width Change (feet)**	Area of Flow Change (acres per mile)	
5-Year Flows					
FR1	38.16	-2.06	-2.00	-0.24	-0.51
FR2	104.91	-1.48	-4.30	-0.52	-0.58
FR3	54.46	-0.08	-0.11	-0.01	-0.15
CR1	181.64	-4.77	-5.42	-0.66	-0.69
BR1	112.07	-7.69	-4.19	-0.51	-0.48
SBC1	47.07	+0.09	+0.03	0.00	+0.01
SBC3	72.71	+0.23	+0.22	+0.03	-0.16
10-Year Flows					
FR1	42.75	-2.01	-2.16	-0.26	-0.57
FR2	128.85	+0.08	+10.19	+1.24	-0.76
CR1	186.54	-0.39	-0.24	-0.03	-0.15
BR1	112.57	-8.15	-4.30	-0.52	-0.45
SBC1	47.23	0.00	0.00	0.00	+0.01
SBC3	74.68	-0.17	-0.15	-0.02	-0.25

Notes:
*Results are only shown for sampling sites that differ from the results provided in Tables 4.6.8-2 through 4.6.8-4.
**Change of width includes both sides of river.
RFFA = reasonably foreseeable future action

4.6.9 Wildlife

Wildlife populations and species composition are directly related to the types, amount, and quality of habitat. Past, present, and future developments such as reservoirs, diversion systems, residential areas and roads, along with other human activities, have the potential to affect wildlife populations and habitat. The affected environment for wildlife is described for Current Conditions (2006) in Section 3.9. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential effects to wildlife are evaluated against Current Conditions (2006).

4.6.9.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Gross Reservoir

Past development and other actions at Gross Reservoir changed the availability and quality of wildlife habitat. Construction of the original reservoir eliminated about 418 acres of ponderosa pine-Douglas fir forests and riparian shrubs and replaced it with aquatic lake habitat. Other developments in and near the Gross Reservoir study area include large-acre residential areas, roads, and a railroad. Other past actions that have affected current availability and quality of wildlife habitat include operation of the dam and reservoir, timber cutting, fire suppression, expanding amounts of dispersed recreation, and forest management including controlled burning, fuels reduction, and thinning. These activities have reduced old growth forests and reduced the area of habitat that is buffered from regularly used roads and trails (effective habitat).

Ground disturbance and inundation from the Proposed Action would permanently affect 465 acres of wildlife habitat and temporarily affect 89 acres at Gross Reservoir. About 90% of the permanent impact would occur in ponderosa pine forest and mixed ponderosa pine, and Douglas-fir forest (see Section 5.9.1.1 for a more detailed discussion of impacts at Gross Reservoir). There are no other RFFAs that would result in more than minor permanent loss of forest habitat at Gross Reservoir. As described in the Land Use analysis (Section 5.16), "land use within the Gross Reservoir area is stable with only minor development or changes planned, such as individual residential building/improvement permits." The area around Gross Reservoir is currently dominated by natural habitats and is expected to continue to be mostly natural.

Construction activities from the Proposed Action would temporarily displace big game and other wildlife during construction, including construction of the dam and clearing of woody vegetation from around the new shoreline of the expanded reservoir. During operation, the enlarged reservoir may lead to some increased boating and fishing, but is not expected to have a large increase in recreational use (Section 5.15).

The direct loss of elk seasonal habitat would be 1-2% of the elk winter concentration area and severe winter range currently used by the herd unit (Section 5.9.1.1). Gross Reservoir is near the eastern end of a migration corridor, and construction activities and the enlarged reservoir are likely to affect elk movement patterns near Pinecliffe. This may result in changed use patterns in winter habitats, and could potentially result in increased conflicts between big game and private landowners. The Project would also result in loss of habitat for small and medium-sized mammals, raptors, other birds, and reptiles and amphibians, and the enlarged reservoir may affect movements of some of these species.

The Proposed Action would affect several types of wildlife habitats of interest in the Arapaho & Roosevelt National Forests (ARNF), including old growth, forested and open corridors, effective habitat, and interior forests. The Proposed Action with RFFAs would affect only a portion of these habitats within the Gross Reservoir study area, and a very small area when compared to the entire ARNF. The Proposed Action with RFFAs would have minor impacts to several of the U.S. Forest Service (USFS) Management Indicator Species (MIS), including pygmy nuthatch, hairy woodpecker, and mountain bluebird, and negligible impacts to golden-crowned kinglet, warbling vireo, and Wilson's warbler. Mountain pine beetle could potentially also affect forest habitats and species in the Gross Reservoir study area. Ponderosa pine is the most common tree at Gross Reservoir and is susceptible to mountain pine beetle. The mountain pine beetle outbreak that began in 1996 in northern Colorado has recently expanded into ponderosa pine forests east of the Continental Divide. Mountain pine beetle activity in ponderosa pine is expected to continue over the next several years, with areas of older and dense trees the most affected. Wildfires also have the potential to substantially affect forested habitats at Gross Reservoir. Because of fire suppression, current forests are more susceptible to fires than in the past, and increased growth of Douglas-fir within ponderosa pine forests has increased the potential for crown fire, which is more damaging. The USFS, Board of Water Commissioners (Denver Water), and other agencies have conducted and will continue to implement programs to reduce the potential for wildfire.

The Proposed Action would occupy portions of two sensitive areas, Winiger Gulch Potential Conservation Area (PCA) and Winiger Ridge Environmental Conservation Area (ECA) (Section 5.9). Dispersed recreation may also affect these areas.

River Segments

For the river segments, past water-related actions, including impoundments, diversions, and inter-basin transfers, have affected stream flows and may have had adverse effects on the extent and type of riparian habitats along the rivers. Larger changes in habitat and wildlife have come from the population growth and development, including clearing of riparian areas to create agricultural land in the larger river valleys, use of irrigation, and development of towns.

Because the Moffat Project does not include any construction activities along the river segments, the analysis of impacts is focused on effects to habitat by 2032 from cumulative changes in flows from the Moffat Project and other RFFAs. Section 4.6.8 provides a detailed analysis of effects to riparian and wetland habitat. That analysis focused on two primary mechanisms that may affect riparian vegetation – lowering of groundwater tables to a degree that causes plant mortality, and changes in the width regularly inundated by stream flows.

The groundwater analysis in Section 4.6.4 indicates that flow changes along the river segments would cause localized, minimal effects to the water table that would not be any larger than stream elevation changes and would be well within the range of normal seasonal fluctuations. Given the small amount of change and complexity of riparian areas, changes are likely to be small in magnitude and patchy in distribution.

Modeling of impacts from stream flow changes is summarized in Section 4.6.8. The analysis is based on detailed hydraulic and vegetation data collected at 12 sampling sites. The largest changes in the 2-year flows would occur on the Blue River and would be about 14 inches in height and 10 feet in width (Table 5.8-4). The width covered by 2-year flows would decrease in the Fraser River and its tributaries, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir; and would increase in South Boulder Creek above Gross Reservoir and North Fork South Platte River, compared to Current Conditions. Decreases in the 2-year flow could result in a gradual narrowing of the stream banks, which would decrease hydrology for wetlands within the banks. Vegetation would respond by gradually adjusting its location, moving downgradient to remain in the same hydrological zone. Changes are likely to be very slow in most areas. The zone of reduced hydrology may show a change in composition to riparian species with somewhat lower water requirements, or to upland species such as conifers. Wetlands and riparian areas that are maintained primarily by groundwater discharge would not be affected.

The analysis in Section 4.6.8 also addresses overbank flooding associated with 5- and 10-year flows. The area of overbank flooding would decrease in the Fraser River, Colorado River, Blue River, and South Boulder Creek below Gross Reservoir, but changes would be relatively small – 1-7 inches in height and 2-6 feet in width. These changes could reduce riparian vegetation density or productivity and cause change in composition including increases in upland species.

The analysis of changes to wetlands and riparian habitats in Section 4.6.8 characterizes changes to riparian and wetland habitats as minor or negligible in the various streams, with changes more likely to involve a shift in composition rather than a loss of habitat. These small changes could potentially affect food availability or cover for riparian wildlife species but are likely to be small and patchy and relatively subtle in most places. These changes are not likely to affect overall distribution or populations of bird, mammal, reptile, and amphibian species.

Changes in stream flows in the Fraser River, Williams Fork, and their tributaries would have negligible effects on moose and elk distribution and population. Moose concentration areas include stream valleys below a number of the diversions, but also include upland areas between the drainages. Elk summer range occurs throughout the Fraser and Williams Fork valleys. Although some changes to riparian and wetland habitats could occur along the streams, the large wetlands and riparian complexes appear to be primarily supported by groundwater and are unlikely to be affected. Cumulative changes in flows are also expected to have negligible impacts to the two USFS MIS that occur along the Fraser and Williams Fork rivers and their tributaries, Wilson’s warbler and boreal toad.

Changes in flow would also have no or negligible effects to PCAs and State Wildlife Areas (SWAs) that occur downstream of the diversions. In the Fraser Valley, the riparian habitats in the PCAs are partly supported by the diverted streams but also obtain hydrology from other streams and/or groundwater discharge. The South Fork Williams Fork PCA includes part of the mainstem of the Williams Fork River, where diversions are expected to have no or negligible effects to riparian habitats. The upper Williams Fork PCA was designated because of occurrences of Colorado River cutthroat trout and boreal toad. As described in Section 5.10, the Proposed Action with RFFAs would have no or negligible effect on boreal toad and on conservation populations of Colorado River cutthroat trout above the diversions. Changes in the Colorado River and Blue River riparian habitats are expected to be negligible. South Boulder Creek east of Gross Reservoir flows through the Hawkin Gulch/Walker Ranch/upper Eldorado Canyon ECA and the Boulder Foothills PCA, but flow changes would not affect the resources for which these conservation areas were identified.

Climate change could have minor to major changes on wildlife, but Project-related impacts would make a negligible contribution to cumulative impacts. Wildlife may respond to warming and changes in precipitation by making latitudinal or elevation shifts in their distribution. Habitats may be degraded, resulting in lower carrying capacity. Movement patterns and seasonal activities may be disrupted. The extent and severity of the effects are unknown at the current time.

4.6.9.2 Alternative 1c with Reasonably Foreseeable Future Actions

At Gross Reservoir, cumulative impacts to wildlife would be similar to those described above for the Proposed Action with RFFAs, but would affect less habitat because the reservoir enlargement would be smaller. Alternative 1c would permanently affect 301.5 acres and temporarily affect 104.7 acres of wildlife habitat.

The proposed new Leyden Gulch Reservoir would permanently remove 389 acres of habitat and would temporarily affect 176 acres (see Section 5.9.2 for more detailed analysis of impacts). Most of the affected area would be grass-forb mix. The new reservoir would affect mule deer summer and winter range and elk winter range but would not affect critical habitats. The new reservoir would affect big game travel routes but is not located in a migration corridor. Other impacts to wildlife include loss of small prairie dog towns and loss of habitat for habitat for migratory birds and small mammals. Operation of the new reservoir would be beneficial to animals that use aquatic and shoreline habitats and would bring them into an area that currently does not support them.

There is a moderate to high potential for additional losses of habitat in the Leyden Gulch Reservoir study area from urban development and other RFFAs. Changes are likely to occur from future industrial/office redevelopment area at the intersection of State Highway (SH) 72 and SH 93, by expansion of residential developments westward into the study area, and from commercial and industrial development along SHs 72 and 93. The currently relatively undeveloped area is likely to become an area of mixed land use. This change in habitat would have a substantial change on the composition of wildlife, with decreases in grassland species and increases in species adapted to urban environments. Potential designation of some of the area as protected open space would maintain some grassland habitat.

Impacts along the river segments would be similar to those described for the Proposed Action with RFFAs.

4.6.9.3 Alternative 8a with Reasonably Foreseeable Future Actions

Cumulative impacts to wildlife at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but would affect less habitat because the reservoir enlargement would be smaller. Alternative 8a would permanently affect 363 acres and temporarily affect 97.9 acres of wildlife habitat.

Filling and operation of the gravel pit reservoirs would create about 200 acres of open water habitat, as well as shoreline habitat. Similar reservoirs are already prevalent along the South Platte River. Other construction activities would affect relatively small areas of previously disturbed land or fragmented natural habitats. Past land development and population growth have already greatly modified the habitats and wildlife within Conduit O and South Platte River Facilities study areas. The largest changes have included development of lake habitats and cottonwood riparian areas along the South Platte River, loss or modification of most upland native prairie, and introduction of noxious weeds and other non-native plants. Project activities combined with RFFAs are unlikely to substantially change the habitats or wildlife in these areas in the future. Continued mining of sand and gravel along the South Platte River in the vicinity of the study area may result in some losses of riparian habitat and increases in industrial and open water areas, which would have minor adverse effects on some species and minor beneficial effects on others.

Impacts along the river segments would be similar to those described for the Proposed Action with RFFAs.

4.6.9.4 Alternative 10a with Reasonably Foreseeable Future Actions

Cumulative impacts to wildlife at Gross Reservoir would be the same as those described for Alternative 8a and would permanently affect 363 acres and temporarily affect 97.9 acres of wildlife habitat.

Construction of the Denver Basin Aquifer Facilities and Conduit M would affect relatively small areas of previously disturbed land and urban land. Impacts would include disturbance during construction, but no long-term changes in habitat. Past land development and population growth has already affected the habitats and wildlife within the Denver Basin Aquifer Facilities and Conduit M study areas. Project activities combined with RFFAs are unlikely to substantially change the habitats in these areas in the future.

Impacts along the river segments would be similar to those described for the Proposed Action with RFFAs.

4.6.9.5 Alternative 13a with Reasonably Foreseeable Future Actions

Cumulative impacts to wildlife at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but would affect less habitat because the reservoir enlargement would be smaller. Alternative 13a would permanently affect 412.7 acres and temporarily affect 93.4 acres of wildlife habitat.

Construction of the South Platte River Facilities and Conduit O would affect relatively small areas of previously disturbed land and urban land. Impacts would include disturbance during construction, but no long-term changes in habitat. Past land development and population growth has already affected the habitats and wildlife within the Conduit O, and the South Platte River Facilities study areas. Project activities combined with RFFAs are unlikely to substantially change the habitats in these areas in the future. Continued mining of sand and gravel along the South Platte River in the vicinity of the study area may result in some losses of riparian habitat and increases in industrial and open water areas, which would have minor adverse effects on some species and minor beneficial effects on others.

Transfer of agricultural water rights would result in conversion of about 3,900 acres of irrigated land to dryland agriculture and the loss of an estimated 82 acres of wetlands and 8 acres of surface water. Transfer of agricultural water rights under this alternative combined with other agricultural water transfer projects, such as the Halligan-Seaman Water Supply Project and NISP, would result in a moderate cumulative loss of aquatic and mesic habitats in rural areas along the Front Range, and changes in the composition of rural wildlife in those areas.

Impacts along the river segments would be similar to those described for the Proposed Action with RFFAs.

4.6.9.6 No Action Alternative with Reasonably Foreseeable Future Actions

The No Action Alternative (i.e., both the Depletion of the Strategic Water Reserve Strategy and Combination Strategy) would not involve any ground-disturbing activities but would involve changes in operation of Denver Water's existing system. These operational changes would change stream flows in the river segments. Other RFFAs would also affect flows, and the following analysis describes total environmental effects from other RFFAs combined with the No Action. Flow changes and the elevation of the 2-, 5-, and 10-year flows would be similar to or less than total environmental effects with the Proposed Action except for the 2-year flow in the Blue River (Table 4.6.8-7). In the Blue River, the total effects with the No Action would reduce the elevation and width of the 2-year flow by 17 inches and 12.7 feet, respectively, compared to 7 inches and 4 feet for the Proposed Action with RFFAs. In the Fraser River, Colorado River, and South Boulder Creek, reductions in the 2-year flow would be about 20 to 50% of those that would occur under the Proposed Action with RFFAs, and effects in the Williams Fork and North Fork South Platte would be similar.

Impacts to wildlife habitat would be similar to those described for the Proposed Action with RFFAs, and are not likely to affect the overall distribution or populations of birds, mammals, reptiles, or amphibians along the river segments.

4.6.10 Special Status Species

The affected environment for special status species habitat is described for Current Conditions (2006) in Section 3.10. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to special status species are evaluated against Current Conditions (2006). Past water- and/or land-based actions in Colorado have had major effects on Federally-listed threatened or endangered species that resulted in them being brought under the protection of the Endangered Species Act (ESA). These species include several Colorado River fishes, Platte River Valley species, and Preble's meadow jumping mouse.

Under Section 7 of the ESA, Federal agencies are required to consult with the U.S. Fish and Wildlife Service (USFWS) prior to authorization of any action that may affect endangered or threatened species. The USFWS issued a Biological Opinion (BO) for the Moffat Project on July 31, 2009. The USFWS subsequently indicated that additional consultation would be required. The U.S. Army Corps of Engineers (Corps) submitted a request for reinitiation of consultation on August 14, 2012 and a Revised Biological Assessment (BA) for depletions and Preble's on August 14, 2013; a Final BO from the USFWS was issued on December 6, 2013 that replaced the July 31, 2009 BO for depletions and Preble's. The Corps is preparing and will submit a Supplemental BA for greenback cutthroat trout. Section 7 consultation will be completed prior to issuance of the Record of Decision.

Other special status species have been less affected by past actions and are less rare or vulnerable than listed endangered and threatened species. U.S. Forest Service (USFS) sensitive species are protected under USFS management policies and guidelines on National Forest land, but rare species on private land have no formal protection. However, if populations were to substantially decline they could be brought under the protection of the ESA. A technical report addressing USFS sensitive species is provided in Appendix G.

4.6.10.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Gross Reservoir

Construction of the Project facilities at Gross Reservoir would not have adverse effects to Federally-listed species and therefore would not contribute to cumulative effects resulting from past actions. Construction activities at Gross Reservoir, however, may affect individuals or habitat of USFS sensitive wildlife species including northern goshawk and flammulated owl, but the Proposed Action would not result in a loss of viability of these species in the Arapaho & Roosevelt National Forests (ARNF) and would not cause a trend to Federal listing or loss of viability range-wide. Under current USFS management policies and guidelines, cumulative effects from other RFFAs are also not likely to result in loss of viability for the ARNF and would not contribute to trend to Federal listing or loss of viability range-wide. More detailed analysis of Project impacts to USFS sensitive animal species at Gross Reservoir is provided in Section 5.10.1.

Construction activities at Gross Reservoir would destroy a large portion of the known populations of several listed ARNF plant species of local concern at Gross Reservoir. The Project may affect the long-term viability for Dewey sedge, Sprengle's sedge, tall blue lettuce, and false melic on ARNF. None of these species are tracked by the Colorado Natural Heritage Program (CNHP), and Project impacts are not likely to affect overall occurrence in Colorado. Local populations of several additional species of local concern would be adversely affected but involve species that are more widely distributed in the ARNF. More detailed analysis of Project impacts to USFS sensitive and local concern plant species at Gross Reservoir is provided in Section 5.10.1.

River Segments

Colorado River Endangered Fish Species. Four Federally-listed endangered fish species – Colorado pikeminnow, razorback sucker, bonytail, and humpback chub – occur downstream of the Project area in the Colorado River. Critical habitat for endangered Colorado River fish extends from Rifle downstream to Lake Powell. Depletions adversely affect the listed species by reducing peak spring and baseflows that limit access to and the extent of off-channel waters such as backwaters, eddies, and oxbows, which are necessary as rearing areas for young fish.

Under the Proposed Action with RFFAs, changes in flow in the Fraser, Williams Fork, Colorado, and Blue rivers would adversely affect endangered Colorado River fish by causing water depletions in the upper Colorado River system, including changes in flow volume and timing. Depletions of any amount are considered by the USFWS to be an adverse impact. Total environmental effects including the Proposed Action would result in an average decrease in flow of 68,200 AF/yr (94.2 cfs) in the Colorado River near Kremmling gage, a reduction of 9% in annual flow compared to Current Conditions (refer to Section 5.1).

About 14,400 AF/yr of decreases in flow in the Colorado River, a reduction of 2% in average years, would result from the Board of Water Commissioners' (Denver Water's) increased diversions through the Moffat Tunnel and Roberts Tunnel. Adverse effects would be mitigated in accordance with the Recovery Implementation Program for Endangered Fish Species in the upper Colorado River Basin (Colorado River Recovery Program). Denver Water's proposed depletions would be covered under its existing recovery agreement, and impacts would be mitigated by payment of a one-time fee to cover the costs of acquisition of water rights and other recovery actions. This requirement will be included as a stipulation in the Section 404 Permit.

Other RFFAs that may affect habitat for Colorado River endangered fish species are described in Section 4.3. Full Use of the Existing System combined with other RFFAs would result in additional decrease in flow of about 48,200 AF/yr (7%) at the Kremmling gage compared to Current Conditions (2006). These additional depletions have either already been addressed by previous Section 7 consultation or will be addressed by future Section 7 consultations. The Proposed Action with RFFAs would result in an additional 2% decrease in annual flow. All projects involving depletions to habitats of

Federally-listed species along the Colorado River will need to comply with the provisions of the Colorado River Recovery Program. The Windy Gap Firming Project (WGFP) and Shoshone Power Plant call reduction would likely have the greatest cumulative effect on flows when added to the effects of the Moffat Project. The effects of the WGFP would occur primarily in wet years because the WGFP would result in additional trans-basin diversions under the Windy Gap water right. The hydrologic effects of the Shoshone Power Plant call reduction would occur primarily in dry years.

Platte River Endangered Species in Nebraska. Several endangered or threatened species occur downstream in the Platte River in Nebraska, including whooping crane, interior least tern, piping plover, pallid sturgeon, Eskimo curlew, and western prairie fringed orchid. Similar to the Colorado River, depletions to the Platte River system are considered by the USFWS to have an adverse impact on endangered species, and specifically on the four target species: whooping crane, least tern, piping plover, and pallid sturgeon.

The Proposed Action combined with other RFFAs would decrease average annual flows at the South Platte River at the Henderson gage by 1%, as shown in Table H-1.75. There would be greater changes in individual months, which would vary from +10% in November and January to -18% in April in average years. Without the Project, decreases in flows from Full Use of the Existing System combined with other RFFAs would be 2% in average years. Wet years would be similar, but dry years would result in increases in flows.

The majority of RFFAs in the South Platte River Basin would rely on water supplies from trans-mountain imports or transferred agricultural water. Projects like the proposed Halligan-Seaman Water Supply Project, which rely to a large degree on transferred agricultural rights, should not affect South Platte River flows since historical return flows must be maintained to prevent injury to downstream water users. Projects that will have the greatest cumulative effects on South Platte River flows when added to the effects of the Moffat Project include the Denver Water Reuse Project, City of Aurora Prairie Waters Project (PWP), and the Northern Integrated Supply Project (NISP). The Denver Water Reuse and Aurora's PWP would decrease South Platte River flows below the cities as they make more use of the reusable return flows. NISP would decrease flows in the Cache la Poudre River and the lower South Platte River, due primarily to the proposed project's reliance on the development of existing and/or new conditional water rights for diversion and exchange of native river water. The USFWS issued a BO for NISP on October 5, 2007.

All projects involving depletions to habitats for Federally-listed species along the Platte River in Nebraska will need to comply with the provisions of the Platte River Recovery Agreement, which addresses cumulative impacts. Depletions to the South Platte River that would adversely affect endangered or threatened species in Nebraska would be addressed under the South Platte Water Related Activities Program.

Preble's Meadow Jumping Mouse. Preble's occur along South Boulder Creek downstream of the South Boulder Diversion Canal, along the South Platte River from below Cheesman Reservoir to Chatfield Reservoir, and along portions of the North Fork South Platte River. All of these river segments would have Project-related changes in flows which were evaluated to assess whether they would have adverse effects to Preble's habitat.

Preble's and Ute ladies'-tresses orchid occur along South Boulder Creek downstream of the South Boulder Diversion Canal. Under Full Use of the Existing System with the Proposed Action with RFFAs, average annual flows would decrease by 3% in average years compared to Current Conditions (Table H-1.67). Average annual flows would be reduced by an average of 8% in wet years with nearly all of the flow reductions occurring in May and June when flows are highest. There would be minimal change in dry years. These changes are not likely to adversely affect habitats used by these species downstream of Eldorado Springs, where riparian habitat occurs along irrigation ditches and laterals as well as along South Boulder Creek. The hydrology of this area is dominated by municipal, industrial, and agricultural water storage and delivery systems.

Preble's also occurs along the South Platte River from below Cheesman Reservoir to Chatfield Reservoir, and along portions of the North Fork South Platte River. Under the Proposed Action with RFFAs, stream flows described below would change due to increased demand and increased deliveries from the Roberts Tunnel.

- For the Proposed Action combined with other RFFAs, changes in the outflow of Cheesman Reservoir (Table H-1.71) would be nearly the same as Current Conditions, but would involve small increases in winter and decreases in most summer months. Dry years would have increased flow in the warmer months. Wet years would be similar to average years. These changes are unlikely to adversely effect riparian habitats used by Preble's between Cheesman Reservoir and Waterton.
- There would be larger changes at the Waterton gage from the No Action Alternative combined with Full Use of the Existing System and other RFFAs (Table H-1.72). Average annual flows would decrease by 13% in average years, by 6% in wet years and 3% in dry years. Decreases in flow would occur during the spring and summer. Most of these decreases would result from full use of Denver Water's existing system. Reduced stream flow in the South Platte River between the Waterton gage and Chatfield Reservoir could affect the distribution and composition of riparian habitat. Based on modeling of impacts in riparian areas (see Section 5.8), impacts to habitat would likely be minor. In addition, riparian habitat in this area may be supported by multiple sources of hydrology including seepage from ditches and ponds, groundwater, South Platte River, and Chatfield Reservoir.
- There would be increased flows in the North Fork South Platte River primarily during summer months in average, wet, and dry years (Table H-1.68). Average annual flows would increase by 26%. Flows would increase substantially from May to October and would decrease from November to March on average. Changes in dry and wet years would be similar. Increased summer flows would inundate riparian vegetation along the edges of the channel, but losses would be minor. Increased summer flows may enlarge the area of riparian habitat.

With the exception of the Chatfield Reservoir Storage Reallocation Project, none of the other reasonably foreseeable future water-based projects described in Section 4.3 would affect flows in the South Platte River between Cheesman and Chatfield reservoirs or along South Boulder Creek. The Chatfield Reservoir Storage Reallocation Project would involve an increase in the normal storage pool at Chatfield Reservoir that would inundate Preble's habitat above the reservoir. Impacts would need to be mitigated by creation of replacement habitat or enhancement of existing habitat.

Although the primary threat to Preble's is the direct loss of habitat area, there are other potential cumulative effects that may adversely affect the structure and function of habitat areas. However, these cumulative effects would be minor, since most Preble's occupied habitat is currently within protected areas. Potential cumulative effects to Preble's due to increased development in the Project area include:

- Increases in stream flows due to increases in impervious surfaces. Residential and commercial building footprints, new roadways, and other compacted urban surfaces can contribute to increased runoff. Such increased flows can cause downcutting in stream channels, altering groundwater hydrology in the riparian zone, and negatively affecting riparian vegetation in Preble's habitat. There may also be increases in stream erosion with subsequent effects on water quality.
- Increases in urban predatory animals that may prey on Preble's. Such animals may include skunks, raccoons, house cats, coyotes, and foxes.
- Increases in animal and plant exotic species. House mice (*Mus musculus*) and Norway rats (*Rattus norvegicus*) are often associated with urban and rural residences and may compete with and prey upon Preble's in upland and riparian habitats. Bullfrogs inhabit slower moving waters and are known predators of Preble's. Construction practices may introduce or help spread weed species such as diffuse knapweed (*Centaurea diffusa*), Canada thistle, and cheat grass that may reduce the viability of Preble's habitat.
- New trails and increased trail use in riparian and upland habitat areas to accommodate an increase in recreational demand.
- Fragmentation of habitat that isolates populations, resulting in decrease in genetic viability and susceptibility to catastrophic events.

Greenback Cutthroat Trout and Colorado River Cutthroat Trout. All of the core conservation populations of Colorado River lineage and greenback lineage cutthroat trout populations in the Fraser and Williams Forks drainages from which water is diverted, are identified as occurring above the Project diversions. The diversions are mostly considered to be complete or partial barriers, and all of the populations are described by Hirsch et al. (2006) as isolated with the exception of North, Middle, and South Fork Ranch Creek, which are considered weakly connected. Fish that move downstream of the diversions are therefore generally lost to the populations above the diversions. The diversions do not include screens to prevent entrainment, and entrainment is likely to occur. The risk of entrainment from operation of the Moffat Collection System is expected to increase because of the increased water diversions and is considered an adverse impact. Other water development projects are not expected to cumulatively affect this species, which mostly occurs in headwater streams.

Canada Lynx. Canada lynx may regularly use riparian areas along some of the tributaries of the Fraser River including Vasquez and St. Louis creeks, and may occasionally use riparian areas along some of the other river segments including Fraser River, Williams Fork and its tributaries, Blue River, and the western portion of South Boulder Creek. Changes in flows in these rivers under the Proposed Action with RFFAs would have negligible to minor effects to riparian habitat. Because lynx primarily use forested areas and have large home ranges, small and localized changes in riparian habitat would be unlikely to affect Canada lynx. With the exception of population growth and development, none of the RFFAs would involve direct loss of habitat, or increases in human activity in lynx habitat.

Ute ladies'-Tresses. Ute ladies'-tresses orchid occur downstream of Gross Reservoir along South Boulder Creek. As discussed for Preble's, flow diversions at the South Boulder Diversion Canal would decrease flow to South Boulder Creek, but changes would be small (average annual flow reduction of 3%) and would be unlikely to adversely affect habitat or populations of Ute ladies'-tresses.

The only RFFA that may affect this species is development. The primary threats are competition from invasive species, vegetative succession, road and other infrastructure construction, and recreation. Most areas that support Ute ladies'-tresses in the South Boulder Creek area are currently protected as part of the City of Boulder's Open Space Management Plan property, and policies are in place that are protective of this species and its habitat. Cumulative effects may occur for populations that are unprotected (i.e., located on private land). These populations are likely to be smaller in size and more isolated from protected populations and, therefore, are more susceptible to changes in hydrology from flood control projects and road construction, competition from introduced weeds, and loss of native pollinators (Fertig et al. 2005).

Modification of wetland habitats resulting from development, flood control, de-watering, and other changes to hydrology is a threat for Ute ladies'-tresses. As development continues in the Boulder area, water use will increase, and water currently used for irrigating crops and hayfields, including areas occupied by Ute ladies'-tresses, may be converted to other uses. Conversion of irrigation water could reduce the quantity and availability of water (especially during the growing season) and reduce groundwater recharge for seeps and springs, resulting in a net loss in area and quality of wet meadow habitat for Ute ladies'-tresses (Fertig et al. 2005).

River Otter. River otters occur along the Fraser, Colorado, and Blue rivers, but the tributaries of the Fraser River and the upper Williams Fork River are not part of their overall range (NDIS 2011). Flow changes would have minor or negligible impacts on riparian habitats along these rivers (Section 5.8), negligible to beneficial impacts to fish in the Fraser River, and no effect to the fish community in the Colorado and Blue rivers (Section 5.11). Changes in water levels would not affect access to dens in winter because flow changes would be relatively small during the winter, 0 to -7% from November to March in the upper and middle Fraser rivers (Tables H-1.29, H-1.33, H-1.38, H-1.44), and -6 to +4% in these months in the lower Fraser, Colorado and Blue rivers (Tables H-1.49, H-1.50, H-1.58, H-1.59, H-1.60, and H-1.64). In addition, river otters choose dens opportunistically and often use beaver bank dens, dams and lodges, and are highly mobile (S. Boyle 2006). Based on these considerations, cumulative impacts would be negligible and would not affect distribution or abundance of river otter.

Boreal Toad. Boreal toads are known to occur along the upper Williams Fork and may occur along the Fraser River and its main tributaries, including Vasquez Creek. They are unlikely to occur along the Blue River and South Boulder Creek upstream of Gross Reservoir, where habitat is marginally suitable and there are no known breeding sites.

Boreal toads have three distinct habitat needs – breeding ponds, summer habitat, and hibernacula. Breeding occurs in a wide variety of water bodies such as beaver ponds, kettle ponds, streams, large reservoirs, and man-made ponds, in areas with shallow, pooled, or slow-moving water. Egg and tadpole development are temperature dependent, and eggs are deposited in shallow warm water that optimizes the warmth of the sun. During the summer, boreal toads use a wide variety of wet and dry, forested and non-forested habitats. Adult boreal toads have been observed spending up to 90% of their life in upland terrestrial habitats (Jones et al. 2001). Hibernation occurs in terrestrial habitats, mostly in underground rodent burrows. Boreal toads may migrate up to about 1.5 miles between breeding ponds and hibernacula. Longer movements of up to 5 to 6 miles between small populations have been recorded.

The Project would not directly or indirectly affect known breeding sites. Boreal toads breed in ponds, most commonly in beaver ponds. The upper Williams Fork boreal toad breeding site is located very near the Williams Fork, but is supported by groundwater and surface flow from a side drainage and is located several feet higher in elevation than the Williams Fork. The Jim Creek and Vasquez Creek breeding sites in the Fraser Valley also appear to be supported by groundwater and have no recent breeding records. The McQueary Lake site in the William Fork valley and the Pole Creek site in the Fraser valley are located far upstream on tributaries.

The Project is unlikely to adversely affect availability of summer habitat and hibernacula. Flow changes are expected to have minor or negligible impacts on riparian habitats (Section 5.8). Boreal toads use a wide variety of habitats during the summer and are not restricted to streamside areas. Large areas of both upland and riparian habitats in the Fraser and Williams Fork valleys are potential summer habitat, and small changes in streamside riparian habitats are unlikely to adversely affect their population or distribution. The Project would not involve any construction activity in their habitat and would not cause direct effects or transmission of disease.

Other RFFAs are also unlikely to affect boreal toad breeding sites or availability of summer habitat and hibernacula.

Interior Least Tern and Piping Plover. These species are very rare migrants at the South Platte River and adjacent reservoirs, and are unlikely to incur impacts from flow changes in the South Platte River under the Proposed Action. Other RFFAs are also unlikely to impact these species.

Common Shiner. There are no recent records of this species in the portion of the South Platte River in the Project area, and it is unlikely to be affected by flow changes under the Proposed Action. Other RFFAs are also unlikely to impact this species.

Other Special Status Species. Stream flow changes resulting from operation of the Project are expected to have no or negligible adverse effect to other special status species and would not contribute to cumulative effects to USFS sensitive species. Flow changes would not noticeably affect availability of suitable habitat for aquatic or riparian species. A more detailed discussion is provided in Section 5.10.1.

Climate Change. Climate change could have minor to major cumulative changes on special status species in relation to changes in their associated habitat, but the extent and severity of cumulative effects are unknown at the current time.

4.6.10.2 Alternative 1c with Reasonably Foreseeable Future Actions

Construction effects at Gross Reservoir would be similar to the Proposed Action with RFFAs. Construction of Alternative 1c would not affect listed Federal or State endangered or threatened species, but it would affect some USFS sensitive animal species and ARNF plant species of local concern. Impacts would be reduced compared to the Proposed Action with RFFAs because of the smaller reservoir size (40,700 acre-feet [AF]).

Construction at the Leyden Gulch Reservoir site is not likely affect to adversely affect Federally- or State-listed endangered or threatened species including Preble's, Ute ladies'-tresses orchid, and burrowing owl. Construction would have localized effects to some other special status species including black-tailed prairie dog and northern leopard frog. The Project combined with other land-based RFFAs is not likely to adversely affect the overall range or populations of these species.

Operation of Alternative 1c would have the same effects on aquatic and riparian species as the Proposed Action with RFFAs. Operation would result in depletions to the Colorado and South Platte rivers, but adverse effects to listed species that occur in and along downstream rivers would be mitigated in accordance with the recovery programs. Operation would not adversely affect downstream habitat for Preble's, Canada lynx, and Ute ladies'-tresses orchid; but conservation populations of greenback cutthroat trout and Colorado River cutthroat trout would be adversely affected by increased entrainment. Operation is likely to have no effects on State-listed species including river otter and boreal toad. Stream flow changes resulting from operation of the Project with RFFAs are expected to have no or negligible adverse effect to other special status species.

Cumulative effects from other RFFAs would be the same as described for the Proposed Action. Other projects involving depletions to the upper Colorado River and to the South Platte River would have to comply with the requirements of the Colorado River Recovery Program and Platte River Recovery Agreement, respectively. Changes in river flows are unlikely to affect Preble's meadow jumping mouse or Ute ladies'-tresses orchid in the Moffat Project area, but increased development is likely to have cumulative impacts. Other water development projects are unlikely to cumulatively affect Greenback cutthroat trout, Colorado River cutthroat trout, Canada lynx, boreal toad, or other special status species.

4.6.10.3 Alternative 8a with Reasonably Foreseeable Future Actions

Construction effects at Gross Reservoir under Alternative 8a would be similar to the Proposed Action with RFFAs. Construction of Alternative 8a would not affect listed endangered or threatened species, but it would affect some USFS sensitive animal species and ARNF plant species of local concern. Impacts would be reduced compared to the Proposed Action with RFFAs because of the smaller reservoir size (52,000 AF).

Construction of the South Platte River Facilities and Conduit O may have temporary affects to burrowing owl, a State-listed species and other special status bird species. Small terrestrial species such as northern leopard frog, common garter snake and black-tailed prairie dog may be killed or injured by construction equipment. Alternative 8a along with other RFFAs, are unlikely to result in adverse cumulative effects to the overall range or populations of these species. About 200 acres of new gravel pit ponds would be created that would provide habitat for bald eagle, white pelican, and other aquatic species.

Stream flow changes resulting from operation of Alternative 8a would have the same effects on aquatic and riparian species as the Proposed Action with RFFAs. Operation of the gravel pit storage ponds would provide shoreline and open water habitat for species such as snowy egret and bald eagle.

Cumulative effects from other RFFAs would be the same as described for the Proposed Action. Other projects involving depletions to the upper Colorado River and to the South Platte River would have to comply with the requirements of the Colorado River Recovery Program and Platte River Recovery Agreement, respectively. Changes in river flows are unlikely to affect Preble's meadow jumping mouse or Ute ladies'-tresses orchid in the Moffat Project area, but increased development is likely to have cumulative impacts. Other water development projects are unlikely to cumulatively affect Greenback cutthroat trout, Colorado River cutthroat trout, Canada lynx, boreal toad, or other special status species.

4.6.10.4 Alternative 10a with Reasonably Foreseeable Future Actions

Construction effects to special status species at Gross Reservoir under Alternative 10a would be the same to those described for Alternative 8a. Construction of Alternative 10a would not affect listed endangered or threatened species, but it would affect some USFS sensitive animal species and ARNF plant species of local concern. Impacts would be reduced compared to the Proposed Action with RFFAs because of the smaller reservoir size (52,000 AF).

Construction of the Conduit M crossing of Clear Creek has the potential to affect Colorado butterfly plant, but pre-construction surveys will be conducted and impacts will be avoided if the species is present. Small terrestrial species such as northern leopard frog, common garter snake, and black-tailed prairie dog may be killed or injured by construction equipment. Alternative 8a along with other RFFAs is unlikely to affect the overall range or populations of these species.

Stream flow changes resulting from operation of Alternative 10a would have the same effects on aquatic and riparian species as the Proposed Action with RFFAs.

Cumulative effects from other RFFAs would be the same as described for the Proposed Action. Other projects involving depletions to the upper Colorado River and to the South Platte River would have to comply with the requirements of the Colorado River Recovery Program and Platte River Recovery Agreement, respectively. Changes in river flows are unlikely to affect Preble's meadow jumping mouse or Ute ladies-tresses orchid in the Moffat Project area, but increased development is likely to have cumulative impacts. Other water development projects are unlikely to cumulatively affect Greenback cutthroat trout, Colorado River cutthroat trout, Canada lynx, boreal toad, or other special status species.

4.6.10.5 Alternative 13a with Reasonably Foreseeable Future Actions

Construction effects at Gross Reservoir under Alternative 13a would be similar to the Proposed Action with RFFAs. Construction of Alternative 13a would not affect listed endangered or threatened species, but it would affect some USFS sensitive animal species and ARNF plant species of local concern. Impacts would be reduced compared to the Proposed Action with RFFAs because of the smaller reservoir size (60,000 AF).

Construction of the South Platte River Facilities and Conduit O may have temporary affects to burrowing owl, a State-listed species, and other special status bird species. Small terrestrial species such as northern leopard frog, common garter snake and black-tailed prairie dog may be killed or injured by construction equipment. About 200 acres of new gravel pit ponds would be created under Alternative 13a that would provide habitat for bald eagle, white pelican, and other aquatic species. The transfer of agricultural water rights on 3,900 acres would adversely affect some species and benefit others. Alternative 13a along with other RFFAs, are unlikely to affect the overall distribution or populations of these species.

Stream flow changes resulting from operation of Alternative 13a would have the same effects on aquatic and riparian species as the Proposed Action with RFFAs. Operation of the gravel pit storage ponds would provide shoreline and open water habitat for species such as snowy egret and bald eagle.

Cumulative effects from other RFFAs would be the same as described for the Proposed Action. Other projects involving depletions to the upper Colorado River and to the South Platte River would have to comply with the requirements of the Colorado River Recovery Program and Platte River Recovery Agreement, respectively. Changes in river flows are unlikely to affect Preble's meadow jumping mouse or Ute ladies'-tresses orchid in the Moffat Project area, but increased development is likely to have cumulative impacts. Other water development projects are unlikely to cumulatively affect Greenback cutthroat trout, Colorado River cutthroat trout, Canada lynx, boreal toad, or other special status species.

4.6.10.6 No Action Alternative with Reasonably Foreseeable Future Actions

Under the No Action Alternative (i.e., both the Depletion of the Strategic Water Reserve Strategy and Combination Strategy), there would be no direct or indirect impacts to special status species from construction of new facilities, but changes in operation of the existing system would result in changes in stream flow in areas occupied by special status species. The impacts associated with these flow changes are discussed below. Because there would be no Federal action, the No Action Alternative would not require nor involve new consultation with USFWS regarding these impacts.

Flow reductions in the Colorado River and impacts to Colorado River endangered fish resulting from the No Action Alternative combined with other RFFAs would be very similar to those modeled for the Proposed Action. In average years they would cause a reduction of 9% in annual flows at the Kremmling gage on the Colorado River (Table H-1.60) compared to Current Conditions. Wet years would have an average flow reduction of 7% and dry years 1%. Flow reductions would mostly occur primarily during summer months. Flow reductions associated with full use of Denver Water's existing system would be covered by the existing Recovery Agreement that Denver Water signed with USFWS in 2000.

For Platte River endangered species, the No Action Alternative combined with other RFFAs would have slightly greater effects than the Proposed Action, compared to Current Conditions. The No Action Alternative combined with other RFFAs would result in an average annual decrease of 2% in flows at the Henderson gage, versus 1% for the Proposed Action (Table H-1.75). Most of the flow reductions would occur in April in average and wet years and there would be small increases in flows in some months. Average annual flows would increase in dry years, with increases in most months.

Flow reductions in streams that support Preble's meadow jumping mouse habitat would be generally similar to the Proposed Action with RFFAs and not expected to result in adverse impacts to this species.

- In South Boulder Creek, average annual flows would decrease by 1% in average years compared to Current Conditions (Table H-1.67), less than the 3% decrease resulting from the Proposed Action combined with other RFFAs. Average annual flows would be reduced by an average of 4% in wet years with nearly all of the flow reductions occurring in May and June when flows are highest. There would be minimal change in dry years. These changes are unlikely to adversely affect habitats used by these species along South Boulder Creek.
- The outflow of Cheesman Reservoir (Table H-1.71) would increase by 1% in average and wet years, and by 12% in dry years. Increased flow in dry years would occur in the warmer months and may result in small increases in riparian vegetation.
- There would be much larger changes at the Waterton gage, similar to, but slightly larger than, the Proposed Action combined with other RFFAs (Table H-1.72). Average annual flows would decrease by 14% in average years, by 7% in wet years and 6% in dry years. Decreases in flow would occur during the spring and summer.
- For the North Fork South Platte, increases in flow would occur in all months in average, wet, and dry years (Table H-1.68).

Under the No Action Alternative, impacts to greenback cutthroat trout, Colorado River cutthroat trout, Canada lynx, and ladies'-tresses would be similar to the Proposed Action with RFFAs, greenback and Colorado River cutthroat trout would be adversely affected by increased entrainment during increased diversions, and the other species would not be adversely affected. Stream flow changes resulting from operation of the Project with RFFAs are expected to have no or negligible adverse effect to other special status species and would not contribute to cumulative effects to USFS sensitive species. Flow changes would not noticeably affect availability of suitable habitat for aquatic or riparian species.

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4.6.11 Aquatic Biological Resources

The affected environment for aquatic biological resources is described for Current Conditions (2006) in Section 3.11. This cumulative impacts analysis evaluates the potential effects of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential effects to aquatic biological resources are evaluated against Current Conditions (2006).

The primary assumption for the Environmental Impact Statement (EIS) analysis is that fish, benthic invertebrates, and their habitat represent the components of the aquatic environment of interest for the Project. Based on public comments received during scoping, comments on the Draft EIS, and discussions with State and Federal agencies, this assumption is appropriate. The Project and other RFFAs involve changes in the hydrologic regime, including changes to the quantity and timing of flow and reservoir storage. This section evaluates cumulative changes in flow and storage patterns in reservoirs that may affect the quality and amount of habitat available for fish and invertebrate species composition and abundance parameters in the Project area. Changes in hydrology can also affect water quality, such as temperature, and can affect channel morphology, and sedimentation. Therefore, the evaluations of changes in water quality, channel dynamics, and riparian vegetation were also considered as part of the cumulative effects analysis for aquatic biological resources and their habitat. Environmental effects are described in greater detail in the Aquatic Biological Resources Technical Report (GEI 2013).

Habitat Simulation Methods

The Physical Habitat Simulation (PHABSIM) was used for evaluating the impacts to fish populations, it simulates a relationship between fish habitat availability and flow in streams. Along with professional judgment, this method was used to evaluate the relative impacts of the Project with RFFAs on the relevant fish and benthic invertebrate parameters described above. PHABSIM information was available for every mainstem section of stream in the Project area with changes in average annual flow of greater than 10 percent (%) and several other sections of stream in the Project area.

PHABSIM data were available from previous work on the Fraser River, Williams Fork River, Blue River, South Boulder Creek, North Fork South Platte River, and the South Platte River (Chadwick and Associates 1986). Recent data at sites on St. Louis Creek, Vasquez Creek, Ranch Creek, the Fraser River, the Colorado River, and the Blue River were also available from the Grand County Stream Management Plan (Grand County 2008, 2010). The output from PHABSIM provides habitat versus flow relationships for different species of fish, based on each species' known habitat preferences. This relationship indicates potential habitat availability, expressed as square feet of weighted usable area (WUA) per 1,000 feet of stream available over a range of flows. Combining this relationship with hydrologic data for a section of stream, fish habitat availability for Current Conditions (2006) and 2032 conditions, the alternatives was calculated and compared.

The PHABSIM output data indicates habitat availability for distinct segments of stream (Table 4.6.11-1). The impacts analysis is organized with respect to the segments of stream established with the available PHABSIM data.

In the Fraser and Williams Fork river basins, there are tributaries with the Board of Water Commissioners (Denver Water) diversions that were included in the Project area. PHABSIM data were not available for most of these tributaries, but R-2-Cross data were available for a two sites on the lower Fraser River. The information at the two sites was used to assess the impacts of the alternatives in tributary streams.

Table 4.6.11-1
Stream Segments Modeled with PHABSIM in the Moffat Project Area

Stream	Segment	Description
Fraser River	1	Headwaters to Vasquez Creek
	2	Vasquez Creek to St. Louis Creek
	3	St. Louis Creek to Ranch Creek
	4	Ranch Creek to Mouth of Canyon
	5	Mouth of Canyon to Colorado River
St. Louis Creek	1	Denver Water Diversion to Fraser River
Vasquez Creek	1	Denver Water Diversion to Fraser River
Little Vasquez Creek	1	Denver Water Diversion to Vasquez Creek
Ranch Creek	1	Denver Water Diversion to Fraser River
Williams Fork River	1	Confluence of Headwater Tributaries to South Fork
Colorado River	1	Windy Gap Reservoir to Williams Fork River
	2	Williams Fork River to Blue River
Blue River	1	Dillon Reservoir to Rock Creek
	2	Rock Creek to Green Mountain Reservoir
	3	Green Mountain Reservoir to Spring Creek
	4	Spring Creek to Colorado River
South Boulder Creek	1	Moffat Tunnel to Pinecliffe
	2	Pinecliffe to Gross Reservoir
	3	Gross Reservoir to South Boulder Diversion Canal
North Fork South Platte River	1	Roberts Tunnel to Buffalo Creek
	2	Buffalo Creek to South Platte River
South Platte River	5	Strontia Springs Reservoir to Chatfield Reservoir
	6	Chatfield Reservoir to Littleton

Life Stages of Fish and Periodicity

Fish pass through several life stages during their lives from egg to adult. Periodicity refers to the time of the year when a life stage is present and PHABSIM are appropriate. In most of the streams and stream segments described in this report, brown trout are self-sustaining and are the dominant species of fish. All life stages of brown trout are present in these populations (Table 4.6.11-2). Brown trout spawn in the fall, and habitat simulations of the spawning life stage are only appropriate for October and November; simulating habitat for spawning brown trout in the spring would be inappropriate and irrelevant to the impacts analysis. Brown trout spawn when flows are low, but further flow reductions between the time of spawning and the time of egg incubation over the winter can be detrimental if the eggs do not remain submerged. Brown trout eggs hatch into fry in the spring, and fry are present through the summer; therefore, the periodicity for brown trout fry is March through September. Juvenile and adult brown trout are present throughout the year, and the periodicity for these two life stages is the entire year.

Table 4.6.11-2
Periodicity of Fish Species in Streams in the Moffat Project Area

Species/Life Stage	Adult	Spawning	Fry	Juvenile
Brook trout	All year	October – November	N/A	N/A
Brown trout	All year	October – November	March – September	All year
Rainbow trout	All year	April – May	June – September	All year

Note:
N/A = not applicable

For rainbow trout, populations are generally maintained through Colorado Parks and Wildlife (CPW) (previously called Colorado Division of Wildlife) stocking, although some natural reproduction may occur. They are stocked as fingerlings (juveniles) or catchable-sized fish (adults). The periodicity for these two life stages is the entire year. Because some natural reproduction likely occurs in some stream segments and may become more common in the future, habitat simulations for spawning and fry was appropriate. Periodicity for these two life stages is April through May for spawning and June through September for fry. For the spring spawning rainbow trout, eggs develop in a short period which coincides with rising spring runoff flows and dewatering of eggs is not a problem with the typical seasonal flow pattern.

Brook trout are present in some of the streams within the Project area. Habitat availability information was available for the adult and spawning life stages. Adults are present throughout the year, and the periodicity for spawning brook trout is October through November. Flow reductions between fall and winter would have similar detrimental effects on brook trout and brown trout. For the fry life stage of brown and rainbow trout, habitat was simulated for the spring and summer months, including the runoff period.

Lower runoff flows in many cases are beneficial in terms of short-term fish habitat availability, a slight reduction in stressful conditions, and a slight advantage in terms of recruitment can occur. However, these advantages still depend upon long-term maintenance of channel processes such as sediment and nutrient transport and proper riparian function.

Seasonal Habitat Changes

For the adult and juvenile life stages of trout that are present throughout the year, habitat availability in most streams usually reaches a minimum during extreme flow conditions, either during the low flows in late winter or during the peak flows of runoff. During low flows, depths may be too shallow to support fish in much of the stream. Reduced habitat availability at high flows reflects the fact that when the stream approaches bankfull depth, velocities are high and low-velocity floodplain habitats and side channels may not be available. During high flows, velocity may become too fast for fish to maintain their preferred position or they may be washed downstream out of their preferred habitat. Reducing habitat availability during the times of the year that experience minimum habitat would reduce the suitability of the stream to support fish and would likely result in adverse impacts. Changes in habitat during other times of the year would have less influence on fish populations.

The fish habitat use criteria used in PHABSIM modeling represent habitat use for trout for the warmer seasons of the year and usually at low to moderate flows, as is common with many PHABSIM studies. Habitat use by fish in winter or at high flows in the study streams may be different. Qualitative studies suggest that trout use a subset of their summer habitat during the winter months. In winter, trout tend to use deeper habitat with slower velocity and slightly larger substrate and may be more oriented to cover. Therefore, using summer low flow habitat criteria for trout in this study may overestimate the habitat actually used in the winter.

Simulated Hydrology

Platte and Colorado Simulation Model (PACSM) simulated hydrology data were used to evaluate indirect impacts at numerous hydrologic nodes, as described in Section 3.1. Impacts were evaluated for two separate comparisons. The first was aquatic resources with existing conditions without the Project using Current Conditions (2006) hydrology compared to Full Use with a Project Alternative (2032) with RFFAs. The second comparison isolated the effects of the Moffat Project alternatives in the comparison to Full Use of the Existing System hydrology (refer to Section 5.11). Each of these comparisons is described in more detail in Sections 4.6.1 and 5.1.

Using the available hydrology data at PACSM nodes corresponding to the stream segments in the Project area, fish habitat availability was simulated with PHABSIM for average years, wet years, and dry years for each of the species and life stages (Table 4.6.11-3), given the periodicity described in Table 5.11-2. Mean daily flow was used as the time step for each of the three-year types. Briefly, average year hydrology included all 45 years in the hydrologic period from 1947 through 1991; wet year hydrology was based on the five wettest years within this period; and dry year hydrology was based on the five driest years within this period.

Output from the Indicators of Hydrologic Alteration (IHA) software (TNC 2006) was also used to evaluate impacts to aquatic resources. IHA estimates changes to many different types of flow components. IHA parameters evaluated in this report include the frequency, timing and magnitude of high flows, small floods, and large floods which can affect aquatic biological resources (Mathews and Richter 2007). The IHA output is discussed in detail in the Surface Water sections of the EIS (Sections 3.1, 4.6.1, and 5.1), but changes to biologically relevant flow parameters are also discussed in this section.

Table 4.6.11-3
PHABSIM Habitat Relationships Available for Stream Segments, Trout Species, and Life Stages in the Moffat Collection System Project Area

Stream	Segment	PACSM Node	Brook		Brown				Rainbow			
			A	S	A	S	F	J	A	S	F	J
Fraser River	1	2580	X	X	X	X		X	X	X		X
	2	2600	X	X								
	3	2720			X	X		X	X	X		X
	4	2810			X	X	X	X	X	X	X	X
	5	2900			X	X		X	X	X		X
St. Louis Creek	1	2200	X	X								
Vasquez Creek	1	2370	X	X								
Ranch Creek	1	2500	X	X								
Williams Fork River	1	3600	X	X								
Colorado River	1	1350			X	X		X	X	X		X
	2	1430			X	X		X	X	X		X
Blue River	1	4250			X	X	X	X				
	2	4500			X	X	X	X	X	X	X	X
	3	4650			X	X		X	X	X		X
	4	4800			X	X		X	X	X		X
South Boulder Creek	1	57100	X	X					X		X	X
	2	57120							X		X	X
	3	57140							X		X	X
North Fork South Platte River	1	50700			X	X	X	X				
	2	50750			X	X	X	X				
South Platte River	1	51290							X	X	X	X

Notes:
Refer to Figure 3.0-1 for the locations of PACSM nodes.
A = adult J = juvenile
F = fry S = spawning

Approach to Cumulative Impacts Analysis

The types of impacts to aquatic biological resources could include beneficial impacts or adverse impacts depending on increases or decreases in the status of the aquatic resources for the Project alternatives with RFFAs in each stream segment and reservoir. Projected changes in flow and modeled habitat (WUA) were a primary component of this cumulative impacts analysis using professional judgment about potential effects of each change on the suitability of the water body to maintain fish and invertebrate populations. Projected changes in water quality, water temperature, channel geomorphology, sediment characteristics, and riparian vegetation were also incorporated into this analysis using professional judgment. The Aquatic Biological Resources Technical Report reviews the approaches to impact analysis from past EISs and presents the rationale for the approach to impact analysis for aquatic biological resources used in this EIS.

There are no standard approaches for impact evaluation and past projects developed approaches appropriate for the specific conditions of the Project. The review of the literature also demonstrates that quantitative relationships between changes in flow or habitat (WUA) metrics and aquatic communities have not been developed and may not exist, especially for benthic invertebrates. Many EISs incorporated information from other resources, such as channel morphology and water quality into the impact analysis. When a threshold for impact intensity was identified, it was usually 10% or greater, with smaller changes assumed to have no impact. Few EISs identified or described impact intensity to qualify the level of impact.

In this EIS, the parameters that were the focus of the analysis of fish populations in streams were the number and density of self-sustaining species. These parameters are widely used in Colorado to describe fish communities. Self-sustaining species are fish species that maintain populations through natural reproduction and, as such, are directly affected by changes in habitat availability, water quality, hydrology, riparian vegetation, channel morphology, and other ecological factors. Stocked fish are also affected by these changes, but their population levels are controlled to a large extent by management decisions by agencies such as CPW.

In most of the coldwater streams in the Project area, the fish communities consist of one dominant trout species and several less common species of trout, as well as species of suckers, and sculpins. The species composition is generally stable, and there are limited opportunities for additional native or introduced species to become established. Therefore, impacts to Project area streams with the alternatives probably would not affect fish species composition very much except in situations of moderate to major changes in the suitability of the stream to support fish.

Parameters used in the analysis of fish in Gross Reservoir were the number and abundance of species. Gross Reservoir is stocked with fish to support recreational fishing and contains a mixture of a few abundant species and many less common species of both self-sustaining and stocked fish. This evaluation focused on the potential effects of the alternatives on the suitability of Gross Reservoir and the proposed Leyden Gulch Reservoir site to support self-sustaining and stocked species of fish. Since the fish community of Gross Reservoir is managed with stocked species, there are more opportunities for additional species to become established compared to the more stable species composition in coldwater streams. The impacts of the alternatives may affect fish species composition to a larger degree in reservoirs than in streams.

The parameters used in the total effects analysis of benthic invertebrates were the number of species present, species composition, including analysis of both taxonomic and functional diversity, and the abundance of invertebrates. These parameters are widely used in Colorado to describe invertebrate communities, and total number of taxa is included in the Colorado Multimetric Macroinvertebrate Index (MMI) as a component metric. Invertebrate communities in streams typically consist of a few abundant species and many less common species, such that as much as 33% of the taxa found in a stream can be found less than 5% of the time (Resh et al. 2005). These benthic invertebrate community parameters are sensitive to changes in habitat availability and water quality. There are many opportunities for invertebrate species introductions in streams primarily because many insects can fly between streams as a method of dispersal. Therefore, changes in the suitability of the habitat in a stream may affect invertebrate species composition to a greater degree than for fish.

Determination of Cumulative Impacts Intensity

An approach to cumulative impacts analysis and descriptions of impact intensity were developed for the Moffat Project EIS based on concepts in past EISs and the conditions present for this EIS (Table 4.6.11-4). An incremental approach to cumulative impacts assessment, which assumes a greater intensity of impacts resulting from a greater change in conditions, was used. Cumulative impacts intensity in this analysis varied from no impact to negligible, minor, moderate, and major impacts. These descriptions of impact intensity primarily evaluated changes in flow and modeled habitat (WUA). Information from other resource areas in this EIS were also incorporated into the analysis including channel geomorphology, sediment characteristics, water quality, and riparian vegetation.

The determination of no impact, beneficial impacts, adverse impacts, and the intensity of impacts were evaluated on a case-by-case basis for each stream segment and reservoir included in the Project area. Differences of less than 10% are likely within the margin of error of the hydrologic and statistical data and would be unlikely to result in adverse or beneficial impacts on fish populations. If key WUA metrics decrease or increase by 10% or less and there are no substantial changes to channel geomorphology, water quality, etc., the combined effects of a Project alternative with RFFAs was considered to be no impact. This assumes there is likely to be no cumulative change in aquatic biological resources.

Table 4.6.11-4
Aquatic Biological Resources Cumulative Impacts and Intensity Descriptions for the Moffat Project with RFFAs

Impact Intensity	Intensity Description
Negligible	The Project with RFFAs would likely result in a slight change to a fish or benthic invertebrate community, but the change would likely not be of measureable or perceptible consequence. Community metrics would fluctuate within the current range of natural variability.
Minor	The Project with RFFAs would likely result in a beneficial or adverse change to a fish or benthic invertebrate community. The change may be small, but measureable and similar to the current range of natural variability. There would likely be no change in species composition for fish and little change in species composition for benthic macroinvertebrates.
Moderate	Beneficial or adverse Impacts on the abundance of fish and benthic macroinvertebrates, their habitat, or the natural processes sustaining them would likely be detectible and readily apparent and outside the current range of natural variability. In coldwater streams and reservoirs there likely would be no change in fish species composition. In warmwater streams and reservoirs there likely would be changes in the number of the less common species. For benthic invertebrates there would be changes in species composition and other community metrics.
Major	The Project with RFFAs would likely result in a substantial and readily apparent beneficial or adverse change to abundance and species composition of the fish and benthic invertebrate communities outside the current range of natural variability.

Negligible cumulative impacts resulted when differences in WUA metrics were less than 10% and there were slight changes in other components, such as flow or channel geomorphology, that would tend to be either favorable or unfavorable but were not substantial. Differences in WUA parameters of less than 10% would be unlikely to result in adverse or beneficial cumulative impacts on aquatic biota, because natural variability in hydrologic and biological data renders a change of less than 10% undetectable. Negligible cumulative impacts would indicate that fish and invertebrate populations would continue to fluctuate within normal historic ranges. Negligible cumulative impacts also resulted when one or more of the WUA metrics had differences of 10% or more but were judged to have no detectible effect on fish. This was the case when the differences resulted in a combination of a small number of favorable or unfavorable changes to WUA among the different fish species and life stages with no consistent trend.

If a difference in WUA metrics was more than 10%, the change was graded according to professional judgment. The impact intensity takes into account the magnitude of the change in a WUA metric, the risk of crossing an ecological threshold and causing a large change in fish or benthic macroinvertebrate species composition or abundance, and projected changes in water quality, temperature, channel geomorphology, sediment characteristics, and riparian vegetation. Minor cumulative impacts would result in small changes to aquatic resources. There would likely be no change in species composition for fish and little change in species composition for benthic macroinvertebrates. Moderate cumulative impacts would result in detectible and readily apparent changes outside the current range of natural variability. Major cumulative impacts would likely result in a substantial and readily apparent change in abundance and species composition of the fish and benthic invertebrate communities far outside the current range of natural variability.

Some of the aquatic resources within the Project area may be near, at, or past ecological thresholds; however, such ecological thresholds have not been empirically determined for any of the stream segments within the Project area, and it is likely that each stream will have its own threshold level. Each stream segment was evaluated to determine if the proposed flow changes would cause the segment to cross a flow-based threshold. If flow-based thresholds were crossed, there was greater likelihood that an ecological "tipping point" may have been crossed as well.

Two flow-based thresholds were used. The first was based on a study by Carlisle et al. (2010), where the risk of fish community impairment increased after a 60% reduction in maximum flows. However, there was considerable variability among the individual streams. This threshold was noted in Section 3.11 because historic flow data were available for some streams in the Project area.

The second flow-based threshold was based on the 1995 study by Baran et al. This study showed that a 60% reduction in average annual WUA produced threshold effects on fish populations (Baran et al. 1995). However, the relationships between flow changes, habitat availability changes, and changes in fish populations are complex, and a 60% reduction in average annual flows does not necessarily create an equivalent reduction in habitat (Section 2.2.3). Because this study showed the effects of a 60% reduction in a measure of average annual available habitat, not a 60% reduction in average annual flows, the use of this threshold assumes a 1:1 relationship between percent flow change and percent habitat loss. Because this is most often not the case, this threshold is conservative.

Both thresholds were used because Project effects could result in one or both of these thresholds being crossed. Under the Ecological Limits of Hydrologic Alteration (ELOHA) concept, crossing both of these thresholds would result in increased risk of a stream segment crossing an ecological tipping point. The possibility of these thresholds points being crossed was considered in the effects analysis and the estimation of impact type and intensity. A determination of crossing an ecological tipping point was made using the available ecological information as well as the flow information.

In this analysis, cumulative impacts on benthic invertebrate community parameters were evaluated based on professional judgment taking into account the available hydrology, water quality, sediment, and channel morphology information. There were no habitat simulations for benthic invertebrates. Reductions in high flows that result in increased sedimentation would be detrimental to macroinvertebrates. However, if reductions in seasonally high spring flows result in flow levels that are still adequate to maintain substrate composition, invertebrates would have more favorable habitat availability with reductions in peak runoff flow. During runoff, high water velocity can limit habitat availability and force refuging behaviors, and movements of the substrate can crush invertebrates. Increases in seasonably low winter flows can also benefit invertebrate populations by increasing the surface area available for supporting these organisms.

4.6.11.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Gross Reservoir

The final surface area of the enlarged reservoir would be 842 acres, over twice that of the existing reservoir with the Proposed Action with RFFAs. The water quality of the enlarged reservoir would be suitable for supporting fish with minimal changes from Current Conditions (refer to Section 4.6.2). One change to the limnology of Gross Reservoir would be the changes in water quality associated with decaying organic matter inundated with reservoir expansion (refer to Section 4.6.2). Although this effect will be minimized by removal of vegetation before inundation, phosphorus and chlorophyll *a* concentrations are expected to increase for a short time after inundation before returning to pre-Project levels. The increased productivity could cause a temporary increase in fish densities, as was observed in a Washington reservoir (Stables et al. 1990). When nutrient and dissolved oxygen levels stabilize after the inundation of new habitat, the increased volume of the reservoir may support larger fish populations. This would be a moderate beneficial impact to the reservoir fishery, since the enlarged reservoir would support more fish than the existing reservoir and may provide opportunities for additional species of fish to become established.

The enlarged reservoir is expected to have short-term increases in levels of methylmercury (refer to Section 4.6.2). This is partially due to the inundation of terrestrial vegetation with the expanded reservoir. Although this would be minimized with the removal of vegetation before inundation, there may be increases in fish tissue levels of mercury for an undetermined period following reservoir enlargement. Therefore, the enlarged Gross Reservoir likely would be on the Section 303(d) List for high levels of mercury in fish tissues like many other East Slope reservoirs in Colorado.

Forsythe Canyon and Winiger Gulch are two small tributary streams to Gross Reservoir and portions of these streams would be inundated with an expanded reservoir. Approximately 1,350 feet of Forsythe Canyon and 2,160 feet of Winiger Gulch would be inundated. There would be a major adverse impact to the fish and/or macroinvertebrate communities in these streams. Approximately 5,000 feet of South Boulder Creek would also be inundated with the expanded reservoir and would transform this section of stream habitat into reservoir habitat. This would represent a major adverse impact to this section of stream but a moderate beneficial impact to the reservoir.

Construction activities during enlargement would not substantially affect the normal operation of the reservoir. The fish and invertebrate communities in the reservoir would continue to function as normal. RFFAs are not likely to have any cumulative effects on aquatic biological resources at Gross Reservoir, beyond those associated with the Moffat Project alternatives, because no major actions that would impact fish or invertebrates sand their habitat are planned in this area.

The enlargement of Gross Reservoir could affect the Rocky Mountain capshell snail if it is present. However, because this species can tolerate a wide range of temperatures and can inhabit a wide range of substrates, it is likely that it would colonize new habitat as water levels rose.

River Segments

Riparian Vegetation, Water Quality, Sediment and Channel Morphology

In most stream sections there would be no cumulative changes to most water quality parameters or riparian vegetation that would affect aquatic biological resources in the Project area due to the Project with RFFAs (refer to Sections 4.6.2 and 4.6.8). In river segments where there would be changes, they are discussed as appropriate. Reductions in flows with the Proposed Action with RFFAs are not expected to have long-term changes to channel morphology in most of the river segments in the Project area (refer to Section 4.6.3). The streams are expected to have similar riffle-pool complexes as Current Conditions (2006). There may be temporary increases in sediment accumulation in isolated locations and some impacts to bank erosion or vegetative encroachment and these are discussed as appropriate.

Fraser River Mainstem

Hydrology data for the Fraser River were available as input for the five PHABSIM segments for fish habitat simulation: PACSM Node 2580 (Fraser River near Winter Park) in PHABSIM Segment 1, Node 2600 (Fraser River below Vasquez Creek) in PHABSIM Segment 2, Nodes 2700 (Fraser River below St. Louis [Hammond Ditch No. 1]) and 2720 (Fraser River below Wastewater Treatment Plant) in Segment 3, Node 2810 (Fraser River below Crooked Creek) in PHABSIM Segment 4, and Node 2900 (Fraser River at Granby) in Segment 5 (Table 4.6.11-3 lists the PHABSIM stream segments). In the Fraser River, the Proposed Action and RFFAs would result in reductions in flow during the runoff period compared to existing conditions (refer to Appendix H, Tables H-1.29, H-1.38, H-1.44, H-1.49, and H-1.50). The timing of the seasonal pattern of spring runoff would not change substantially although the magnitude and duration would be reduced in some years. The

Proposed Action, Full Use of the Existing System with RFFAs would increase the frequency and duration of dry years in the Fraser River in Segments 1, 2, and 3 (refer to EIS Section 4.6.1).

Native flow depletion for the Fraser River downstream of the Denver Water diversion (PACSM Node 2120) averages 67%, and monthly peak flows in average and dry years are 61% and 85%, respectively. The additional flow changes associated with Full Use of the Existing System, RFFAs, and Project conditions would be 79% on average and up to 88% in peak flow months. The cumulative removals from Full Use of the Existing System, RFFAs, and Project conditions would exceed the 60% peak flow removal threshold established by Carlisle et al. (2010) and cross the 60% average annual flow removal threshold established by Baran et al. (1995). Therefore, the depletion information indicates the Fraser River could be near the tipping point. The other factors are evaluated below to determine the risk of crossing a tipping point.

Reductions in flow in late summer could affect water temperatures in the Fraser River from Fraser to Granby (PHABSIM Segments 2 through 5). Historically, there have been only two days of daily maximum temperature exceedances in these segments (refer to Section 4.6.2). The correlation with flow and water temperature is negative but weak, and variation in water temperature at low flows is extremely high; air temperature is much more likely to affect water temperatures in this stream. There are not expected to be more frequent temperature exceedances (refer to Section 4.6.2).

There would be no long-term increase in sediment deposition with the Proposed Action with RFFAs. Flushing flows would be sufficient throughout the length of the Fraser River. Therefore, there would be no long-term increase in habitat for the *T. tubifex* that carry whirling disease. Water temperatures are expected to be similar to Current Conditions on most days. Overall, RFFAs and the Proposed Action would not have cumulative effects on whirling disease in the Fraser River. Adequate flushing flows and the similarity in baseflows in late summer and in the sediment transport capabilities of the Fraser River indicate that the Proposed Action with RFFAs would have no effect on Didymo as well. The Proposed Action with RFFAs would not change the current system of diversions and canals and would not introduce any new pathways for nuisance species distribution.

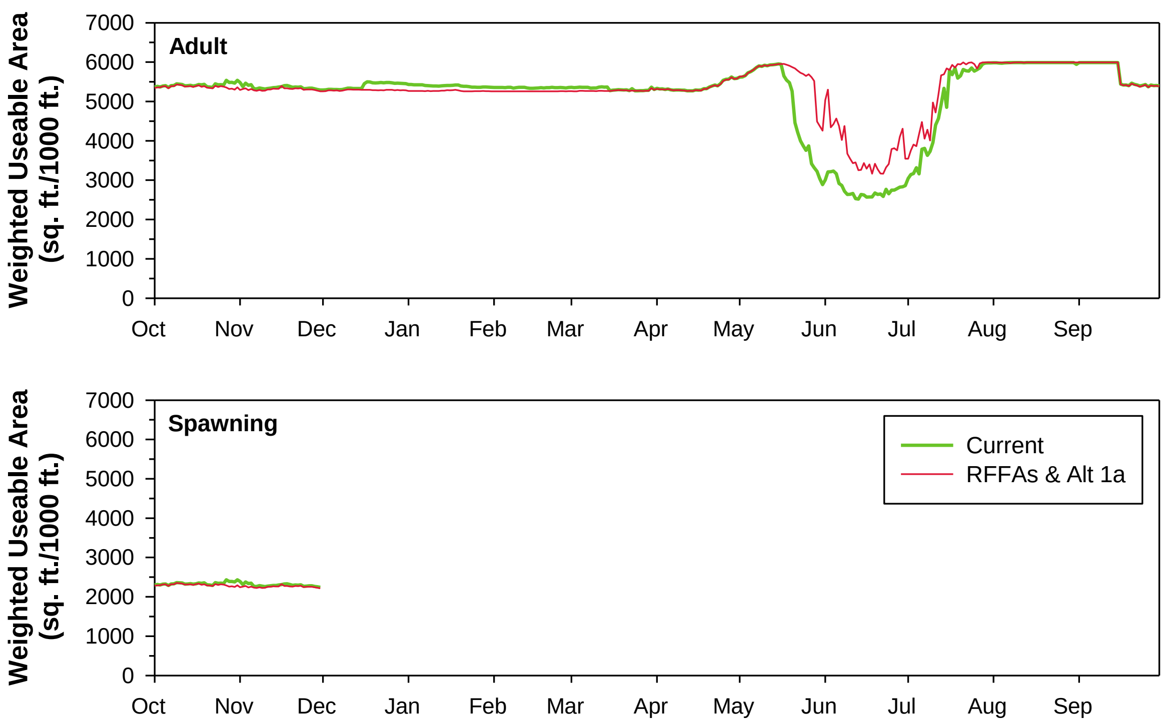
Segment 1, Headwaters to Vasquez Creek

In average years, Segment 1 flow reductions (as a percentage of existing monthly flow) would be 38% in May, 49% in June, and 23% in July (refer to EIS Section 4.6.1); flow reductions in the remaining months would not exceed 6%. The spring snowmelt runoff peak flow would be reduced by 17 cubic feet per second (cfs) (29%) on average and 6 cfs (3%) in wet years (refer to Appendix H, Tables H-14.4 and H-14.5). In dry years, reductions in existing flows would only occur from June to September and would range from 9% in September to 17% in June and July. In wet years, reductions to existing flows would only occur from May through August and range from 3% in August to 51% in May.

IHA analysis of the Fraser River just downstream of the diversion (PACSM Node 2120) shows that the Proposed Action with RFFAs would result in only an 8% reduction of the 90-day minimum flow. IHA high flow parameters would be similar to Current Conditions with respect to frequency, timing, duration, and magnitude because natural high flows are already diverted under Current Conditions. IHA small flood and large flood parameters look at floods that occur less frequently than once every two years. The characteristics of small and large floods in Segment 1 of the Fraser River would not change appreciably because they have already been altered by diversion and do not occur every year under Current Conditions. However, small and large flood duration would be reduced by approximately 30% compared to Current Conditions.

Brook trout are the dominant species in Segment 1 of the Fraser River. PHABSIM habitat relationships are available for brook, brown, and rainbow trout for this segment of the river from the Grand County Stream Management Plan (Grand County 2010). In Segment 1, brook trout adult habitat is most limited during peak runoff in median and wet years and during late summer, fall, and winter in dry years. Reductions in minimum and average annual habitat availability never exceed 2% in any year type. The largest change in habitat availability is a 26% increase during the spring runoff period in median and wet years (Figure 4.6.11-1), which may represent a reduction in stressful habitat conditions for brook trout. There would be minimal cumulative changes in spawning habitat availability.

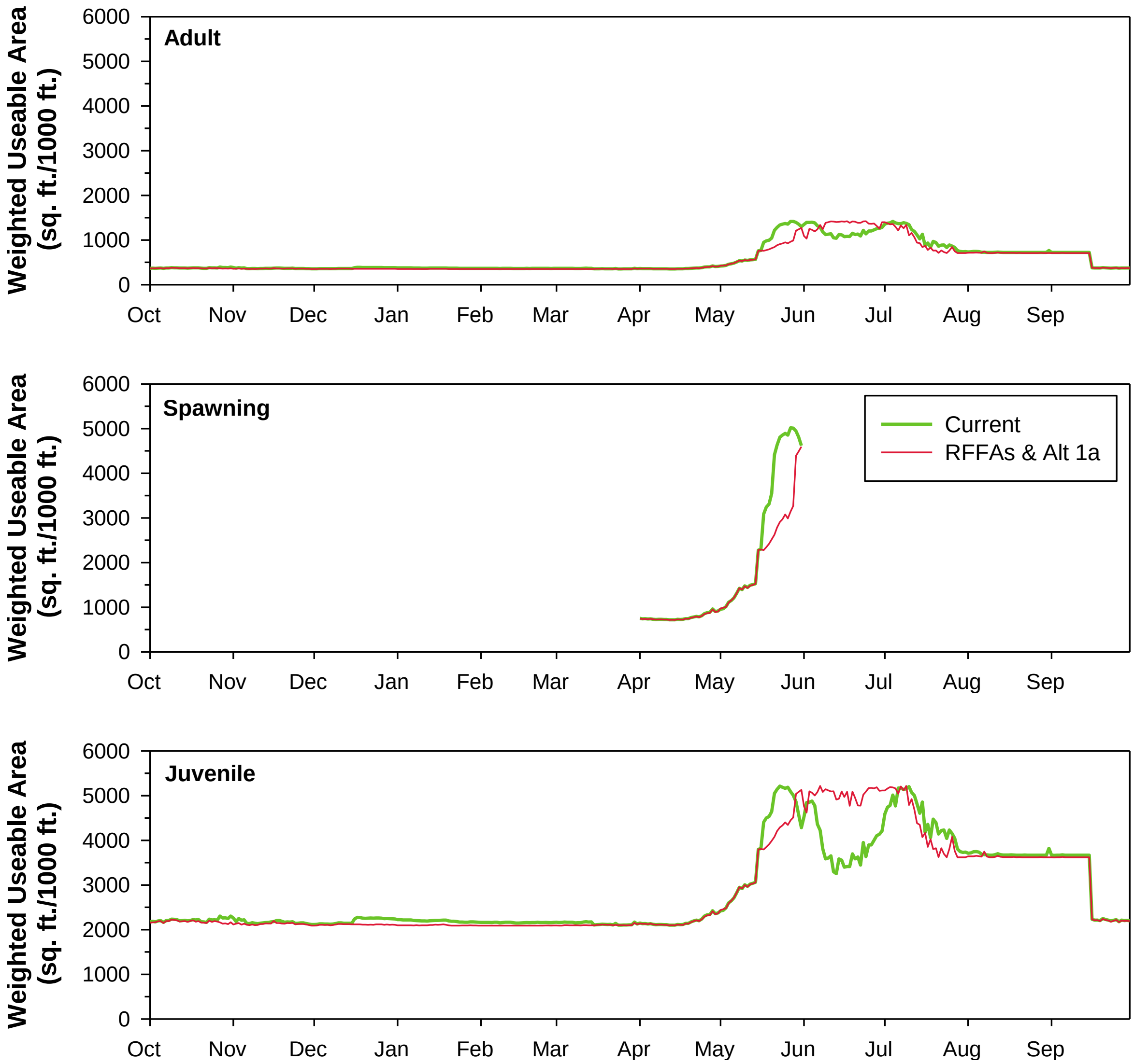
Figure 4.6.11-1
WUA for Adult and Spawning Brook Trout in Segment 1 of the Fraser River for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



Adult and juvenile brown trout habitat availability is highest during spring runoff and most limited in winter. Reductions in minimum habitat availability for all life stages never exceed 3%, and reductions in average annual habitat availability for all life stages never exceed 4%.

Adult and juvenile rainbow trout habitat availability is lowest during winter and early spring and highest during peak runoff, similar to brown trout (Figure 4.6.11-2). In all three year types, reductions in minimum habitat availability for all life stages never exceed 4%, and reductions in average habitat availability for most life stages never exceed 5%. Average spawning habitat availability would be reduced by 17% in median years (Figure 4.6.11-2) and by 10% in wet years.

Figure 4.6.11-2
WUA for Three Life Stages of Rainbow Trout in Segment 1 of the Fraser River for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



The Proposed Action, Full Use of the Existing System, and other RFFAs would increase the frequency and duration of dry years in the Fraser River. For brook trout, the dominant species in Segment 1, dry years result in more favorable habitat availability that median and wet years. In wet and median years, spring runoff flows result in low habitat availability for brook trout adults. The reduced peak flows in dry years result in substantially higher minimum habitat availability during the runoff period. For brown and rainbow trout, habitat availability in wet, dry and median years is similar for much of the year, but is lower in dry years during the runoff period.

The available literature suggests that benthic macroinvertebrates are less sensitive to flow reductions than fish. Because some macroinvertebrates can be dislodged during peak flows, some species can benefit from reduced runoff. As a result, macroinvertebrate communities that exist after the flow reductions with the Proposed Action with RFFAs may include more species and higher densities than Current Conditions. However, macroinvertebrates with more generalized flow requirements may replace rheophilic species, leading to changes in the invertebrate community and similar or lower species richness. If rheophilic species persist or are replaced by generalist species that fill similar ecological roles, reductions in runoff flows with the Proposed Action with RFFAs could have a minor beneficial or negligible impact on the macroinvertebrate community of the Fraser River. The Fraser River in this segment is on the Section 303(d) List for aquatic life (provisionally listed) due to the samples with low MMI scores, although some samples scored above the threshold as well. The Proposed Action with RFFAs would not likely change MMI scores substantially.

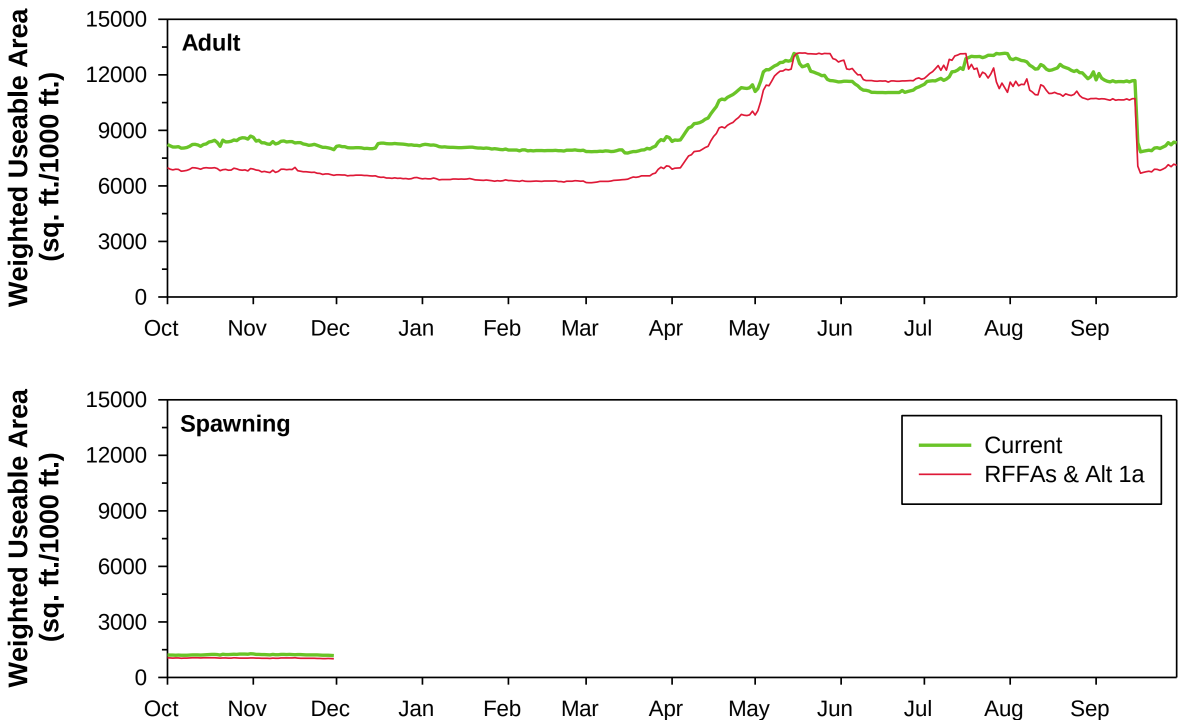
Cumulative changes in sediment transport are expected to be minor. There may be changes in short-term sediment cycling that allow sediment to temporarily accumulate but sediment would be removed by periodic high flows, and no long-term change in channel morphology is expected (refer to Section 4.6.3). Very limited exceedances of water quality standards for copper and zinc already occur in the upper Fraser River and there are likely to be further occurrences in the future (refer to EIS Section 4.6.2). Projected habitat availability and temperature changes in this segment of the Fraser River as a result of the Proposed Action with RFFAs would not be sufficient to affect trout populations in Segment 1. Also, long-term aggradation is not expected, so spawning habitat would not become permanently embedded. However, the short-term accumulations of sediment and the likely changes in benthic macroinvertebrate species composition indicate that the Proposed Action with RFFAs would have minor adverse cumulative impacts on aquatic resources in Segment 1 of the Fraser River. This segment of the Fraser River has not crossed ecological tipping points that would affect the suitability to maintain fish and invertebrate populations and likely will not cross a tipping point with the Proposed Action with RFFAs.

Segment 2, Vasquez Creek to St. Louis Creek

In Segment 2, substantial flow reductions would occur throughout the year due to the Project with RFFAs. In average years, reductions in monthly flow would range from 23 to 45%, reducing flows up to 61 cfs (refer to Appendix Table H-1.38). Dry year reductions would not be part of the Proposed Action, but reductions from other RFFAs would range from 22 to 42% (up to 8 cfs), and wet year reductions would range from 14 to 45% (up to 89 cfs).

The habitat relationship for adult brook trout for Segment 2 of the Fraser River indicates that the low flows of winter result in relatively low habitat availability (Figure 4.6.11-3). There is approximately half as much habitat availability in winter as compared to the summer months. Minimum habitat availability for adult and spawning brook trout occurred in fall and winter in median, dry, and wet years. The reductions in flow with the Proposed Action with RFFAs would result in reductions in minimum habitat availability in median, dry, and wet years of up to 21% for adults and up to 22% for spawning brook trout.

Figure 4.6.11-3
WUA for Adult and Spawning Brook Trout in Segment 2 of the Fraser River for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



Cumulative effects on average habitat availability were slightly smaller than they were for minimum habitat availability. Median year decreases were 11% for adults and 15% for spawning fish (Figure 4.6.11-3), dry year decreases were 17% for both life stages, and wet year decreases were 8% for adults and 9% for spawning fish.

There would be an increase in frequency of dry years (see Section 4.6.1 for a definition of dry years) with the Full Use of the Existing System, and the Proposed Action with RFFAs. For brook trout adults, dry years have slightly lower average habitat availability but up to 15% lower minimum habitat availability than median and wet years.

There would be temporary changes in short-term sediment cycling, but sediments would continue to be removed by periodic high flows, and no long-term aggradation is expected (refer to Section 4.6.3). Because sedimentation appears to be concentrated near diversions and is not pervasive throughout the segment, spawning habitat should not be affected. There would be no temperature changes in this segment of the Fraser River as a result of the Proposed Action with RFFAs sufficient to affect trout populations. There may be changes in macroinvertebrate species composition as rheophilic species are reduced and replaced by species that prefer lower current velocity. The reductions in habitat availability would result in decreased brook trout populations in Segment 2 of the Fraser River. Moderate adverse cumulative impacts to aquatic resources is expected as a result of reduced fish habitat availability and changes to the macroinvertebrate community with future actions. This could result in reductions in brook trout populations in this segment of the river. However, cumulative impacts are not expected to preclude the maintenance of fish and invertebrate populations and this segment would not be degraded past a tipping point. The Fraser River in this segment is on the Section 303(d) List for aquatic life (provisionally listed) due to the samples with low MMI scores, although some samples scored above the threshold as well. Proposed Action with RFFAs would not likely change MMI scores substantially and they may continue to indicate impairment in the future.

Segment 3, St. Louis Creek to Ranch Creek

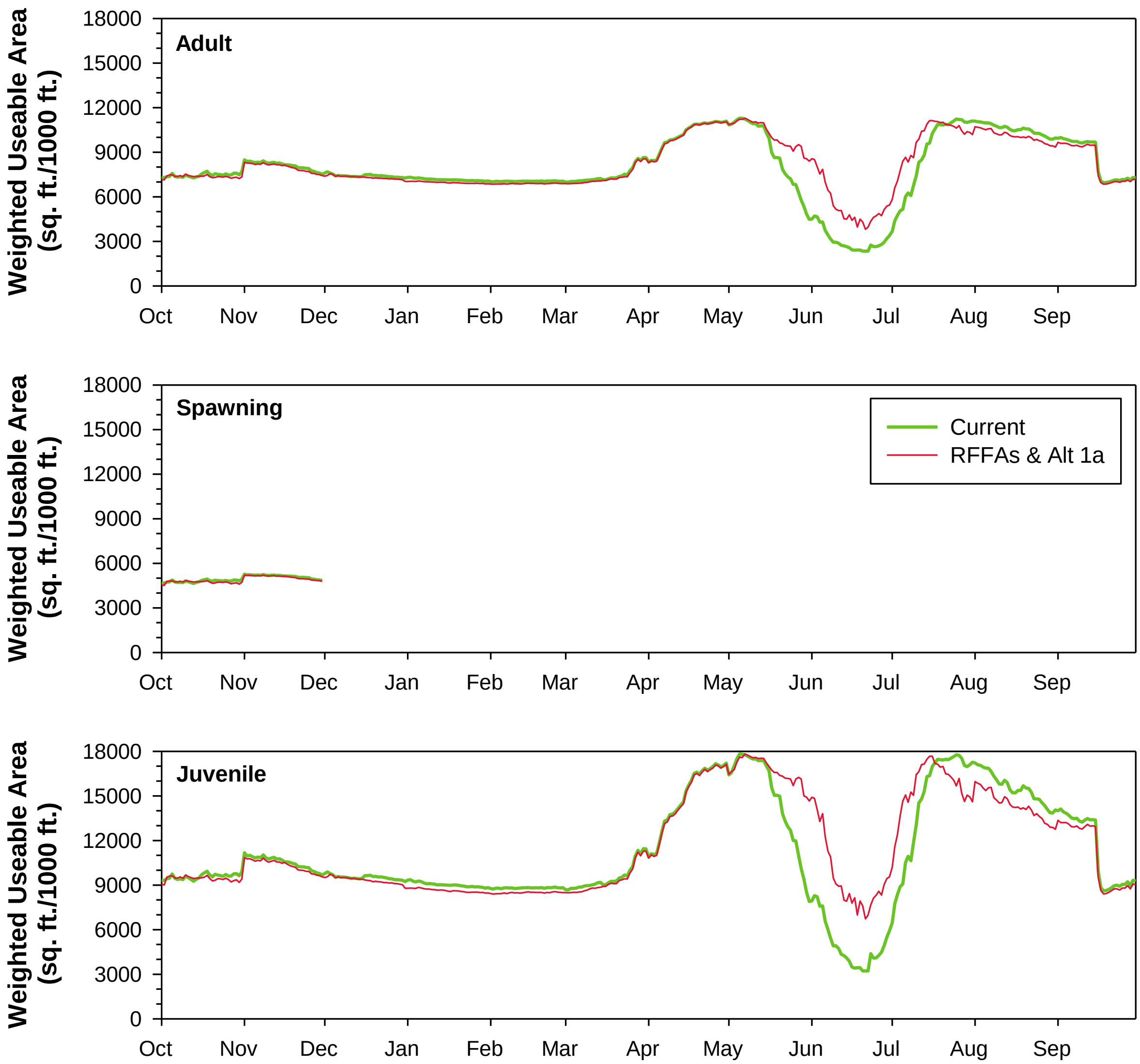
In Segment 3 of the Fraser River, monthly flows would be 21 to 54% lower and up to 91 cfs lower throughout the year than Current Conditions in average years. Peak flows would be reduced by 100 cfs (33%) in average years (refer to Appendix H, Table H-14.4). In dry years, the RFFAs would cause flow reductions that would range from 21 to 65% (up to 14 cfs), and in wet years, the Proposed Action with RFFAs would cause reductions that would range from 13 to 46% of current flows (up to 124 cfs).

IHA analysis of flows in the Fraser River downstream of St. Louis Creek (PACSM Node 2700) shows that the Proposed Action with RFFAs would result in 90-day minimum flow reductions of 57% and a few days of zero flow modeled in some years. Although the largest amount of water would be withdrawn during peak flows, the Fraser River would still experience runoff flows, albeit reduced, in June and July. The spring snowmelt runoff would peak a few days sooner and have a shorter duration than the existing flow peak. The high flow parameters would be similar in magnitude, duration, and frequency but would occur approximately six weeks sooner in spring. Small and large floods would remain unaffected with respect to timing and magnitude, but the duration of large floods would decrease by 31%.

In Segment 3 of the Fraser River, habitat relationships were available for adult, juvenile, and spawning life stages of rainbow and brown trout. In this segment, minimum habitat availability for brown trout and rainbow trout occurs during peak runoff in median and wet years and during low flows in dry years (Figure 4.6.11-4). The juvenile life stage of both species has a similar pattern of habitat availability as adults.

Under the Proposed Action with RFFAs, peak runoff flows would be reduced and minimum habitat availability would increase by 63% for adult brown and rainbow trout in median years. For juvenile brown and rainbow trout, minimum habitat availability would increase by 109% and 88%, respectively in median years. Average annual habitat availability would not change by more than 5% for any life stage of brown or rainbow trout. Habitat availability would remain largely unaffected during low flows (Figure 4.6.11-4). The large increases in juvenile and adult minimum habitat availability would occur in median years because lowest habitat availability occurred during peak runoff. This may represent a reduction in stressful conditions for these life stages. In dry and wet years, changes in habitat availability for all life stages of brown and rainbow trout would be 5% or less.

Figure 4.6.11-4
WUA for Three Life Stages of Brown Trout in Segment 3 of the Fraser River for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



The increased frequency of dry years with the Proposed Action, Full Use of the Existing System, with RFFAs would lower peak spring flows in Segment 3. For brown trout, dry years result in 165% and 113% higher minimum habitat availability for adults and juveniles, respectively, than wet years because of higher habitat availability during runoff. For rainbow trout juveniles, minimum habitat availability in dry years would be several times higher than in median and wet years due to the reduced peak flows and for adults, minimum habitat availability would be 70% higher in dry years than in wet years.

Temperature exceedances in Segment 3 of the Fraser River occasionally occur and are not expected to increase as a result of RFFAs and the Proposed Action. Sediment and channel morphology are not expected to change. However, the reductions in peak flows and increased frequency of dry years would increase habitat availability for fish and likely for macroinvertebrates as well. The Proposed Action with RFFAs would have a moderate beneficial cumulative impact to aquatic resources in Segment 3 of the Fraser River.

Segment 4, Ranch Creek to Mouth of Canyon

In Segment 4, monthly flow reductions in average years would range up to 21% (up to 104 cfs) and would be greatest in June and July; but reductions during late summer low flows would be as high as 12%. Peak flows would be reduced by 21% (115 cfs) (refer to Appendix H, Table H-14.4). Flow reductions due to the RFFAs would not exceed 13% (8 cfs) in dry years, but reductions of up to 10% would occur during summer low flows. In wet years, flow reductions would be greatest in May and June (13%, up to 140 cfs), but they would be as high as 12% during summer low flows.

IHA analysis of the Fraser River below Crooked Creek (PACSM Node 2810) shows that the Proposed Action with RFFAs would result in no reduction of 90-day minimum flows. Low and high pulse counts and durations would not change. The spring snowmelt runoff would be similar to Current Conditions with respect to timing and duration. The frequency, timing, and duration of high flow parameters and small floods would not change substantially. Large floods would be reduced in magnitude (18%) and duration (17%), but timing would not change significantly.

PHABSIM habitat relationships were available for adult, juvenile, fry, and spawning life stages of rainbow and brown trout. Minimum habitat availability for brown trout would not be changed by more than 2% for any life stage in median, dry, or wet years. Average annual habitat availability would not be changed by more than 3% for any life stage in median, wet, or dry years. Habitat availability during low flows would not be affected.

Minimum habitat availability for rainbow trout would not be changed by more than 5% under the Proposed Action with RFFAs for most life stages. However, an increase in minimum fry (54%) and juvenile (14%) rainbow trout habitat would occur under the Proposed Action with RFFAs in median years because the minimum habitat availability for both of these life stages currently occurs during peak runoff. This increase in minimum habitat availability may represent a decrease in stressful conditions for these stages of rainbow trout. Changes in average annual habitat availability for all year types would be 6% or less for all life stages except spawning. Reductions in average annual spawning habitat would be 13% in median years, 10% in dry years, and 5% in wet years. However, the prevalence of whirling disease has essentially prevented rainbow trout reproduction in the Fraser River. Efforts to establish whirling disease resistant Hofer-strain rainbow trout populations could be negatively affected by this reduction in spawning habitat.

For almost all life stages of brown and rainbow trout there would be minimal changes in habitat availability in this segment of the Fraser River. Exceedances of temperature standards have not occurred in this segment and changes are expected to be minimal. Changes to sedimentation and channel morphology are not expected. The result of the Proposed Action with RFFAs would be negligible cumulative impacts to aquatic resources compared to Current Conditions, and density changes to existing fish and macroinvertebrate populations are not expected.

Segment 5, Mouth of Canyon to Colorado River

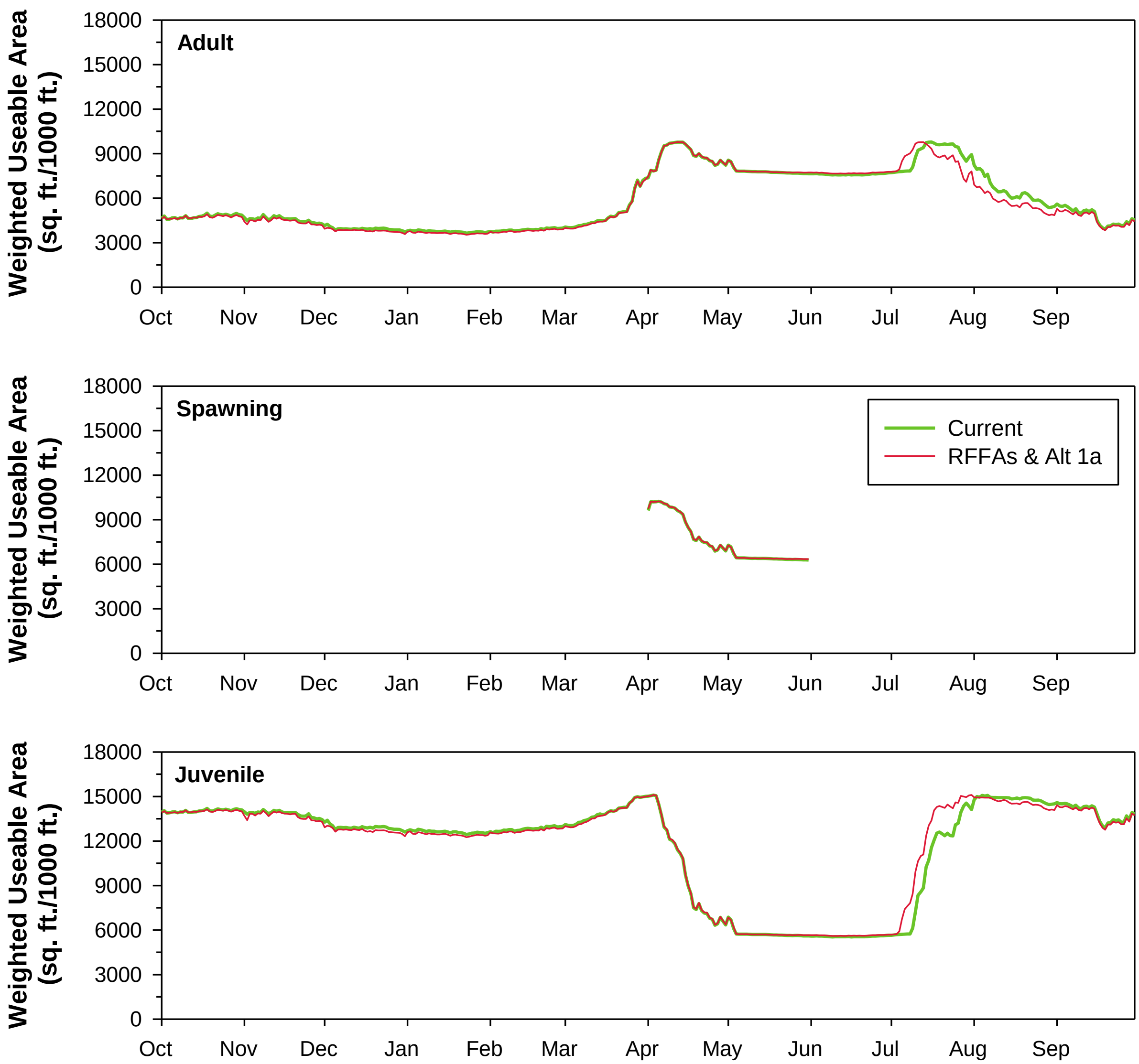
In Segment 5, average year flow reductions would range from 14 to 21% (up to 106 cfs) from June through August due to the future actions; reductions would be 7% or less in remaining months (refer to Appendix Table H-1.50). In dry years, reductions would be 10 to 16% (up to 9 cfs) from June through August due to RFFAs, and in wet years, depletions would range from 11 to 13% (up to 141 cfs) from May through August; depletions would be no more than 9% in remaining months.

Habitat simulations for brown trout indicate minimal changes in minimum and average annual habitat availability of 2% or less for all life stages in median, dry and wet years. Habitat availability during low flows would remain unaltered. The Proposed Action with RFFAs would not result in minimum habitat availability changes for rainbow trout greater than 3% for any life stage in any year type. Average annual habitat would not change by more than 4% for any life stage or year type (Figure 4.6.11-5). Habitat during low flows would not be reduced.

Low winter flows usually occur in January and are generally above 30 cfs in median and wet years. In dry years, low flows under Current Conditions (2006) and under the Proposed Action with RFFAs would be approximately 23 cfs. These flows are similar to the recommended minimum flows based on R-2-Cross data (20 cfs and 30 cfs at two sites) and would not change substantially with the Proposed Action with RFFAs.

The small reductions in peak flows under the Proposed Action with RFFAs would have little effect on fish habitat availability in Segment 5 of the Fraser River. Temperature changes are expected to be minimal and would not affect trout populations in Segment 5. Also, long-term sedimentation is not expected, so spawning habitat would not become permanently embedded. Therefore, the Proposed Action with RFFAs are expected to have negligible cumulative impacts to aquatic resources in Segment 5 of the Fraser River.

Figure 4.6.11-5
WUA for Three Life Stages of Rainbow Trout in Segment 5 of the Fraser River for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



Fraser River Tributaries

There would be additional diversions on tributary streams in average, dry, and wet years with the Proposed Action with RFFAs compared to existing conditions. There would be no additional diversions in dry years in any of these streams with the Project with RFFAs, although there would be additional diversions under Full Use of the Existing System in most streams in dry years (refer to Section 4.6.1). The Proposed Action, Full Use of the Existing System, and other RFFAs would increase the frequency and duration of dry years in some of the Fraser River tributaries (refer to Section 4.6.1). The timing of the seasonal pattern of spring runoff when flows bypass the diversions would not change substantially although the magnitude and duration would be reduced in some years. Many of the tributary streams are fully diverted at times with no flow past the diversion. Days when the streams are fully diverted are zero flow days. The number of zero flow days changes with the Project in some streams and was evaluated.

Many of the tributary streams are fully diverted at times with Current Conditions, have limited or no fish population, and have macroinvertebrate communities limited to species that can tolerate long periods of low flows. Even on zero flow days, many of these streams also have groundwater and wetland inputs that allow more robust aquatic communities at increasing distances downstream of the diversions. Most of these streams are already past ecological tipping points.

Based on information collected from Jim Creek, many of the tributaries that are fully diverted at times are currently undergoing channel narrowing and vegetative encroachment. With flow reductions as a result of the Proposed Action with RFFAs, this narrowing could continue or be accelerated (refer to Section 4.6.3). This could be the case with many of the Fraser River tributaries without bypass flows.

Decreasing flows in these streams could affect aquatic communities in several ways. During wet periods when flows pass the diversions, there are macroinvertebrates and, possibly fish, which also pass the diversions. These organisms may become part of the community downstream of the diversions, even if for just a short period. Also, these organisms may recolonize previously dry sections of streams or augment populations in recovering sections of groundwater inputs. Ultimately, these organisms may travel downstream to more permanent and robust communities in larger sections of stream. Decreasing the magnitude and/or duration of flow during wet periods of the year would decrease the connectivity with upstream fish and invertebrate populations. Decreasing the length of time a stream section has flowing water would limit or prevent the temporary use of stream sections by fish and invertebrates. Some species of invertebrates can survive in streams that go dry if the streams have a sufficient period for the invertebrates to complete the aquatic parts of their life cycle. These species can become part of the terrestrial environment or downstream aquatic communities after the stream sections are dry. Also, fish, especially young fish, may temporarily use sections of stream that will later be dry. Finally, flows bypassing diversions during wet periods can augment the amount of water available downstream in gaining sections of stream resulting in larger area and more favorable conditions for some species allowing for more robust communities. Reducing flows in wet periods would limit these beneficial effects.

St. Louis Creek Tributaries

PACSM Node 2180 for the St. Louis Creek tributaries (refer to Appendix H, Table H-1.41) includes the hydrology data for West St. Louis Creek, Short Creek, Iron Creek, Byers Creek, East St. Louis Creek, and Fool Creek. The Proposed Action with RFFAs would divert 46% more water from these streams in average years and 24% more water in wet years on an average annual basis; no additional diversions are proposed for dry years. The average year peak flow would be reduced by 39% (refer to Appendix H, Table H-14.4). The diversions would occur from May through September; because flows are already nearly 100% diverted in the remaining months. The additional diversions would extend the period of no flow by approximately two weeks on average (refer to Section 4.6.1), although there would be one year with up to 63 additional zero flow days. There is no bypass flow for these streams.

IHA analysis of Node 2180 shows that the Proposed Action with RFFAs would result in no reduction in minimum flows, because these tributaries are currently 100% diverted for most of the year. The remaining flows in the St. Louis Creek tributaries occur during spring runoff. These spring flows would be reduced under the Proposed Action with RFFAs so that flows that would be high enough to meet the IHA high flow parameter would decrease from 1 to 0 occurrences per year, and the duration of high flows would decrease by 33%. Small flood magnitude would decrease by just under 10% but duration would be reduced by 60%, and large floods would remain largely unaffected in terms of magnitude but duration would decrease by 42%.

All of these tributary streams are currently severely diverted and are often dry below the diversions. The hydrology data for these streams indicate that water passes the diversions only during the high flow months in most years, May through July. During the rest of the year the streams are fully diverted and resume flowing at varying distances downstream as water enters the streams from tributaries, groundwater, and wetlands. The periods in severely diverted streams when water does not pass the diversions represent stressful conditions for aquatic organisms, especially in winter, the period of lowest flow and cold temperatures. The Proposed Action with RFFAs would not change flow conditions during the critical winter months in the St. Louis Creek tributaries, but would reduce the flows that pass the diversions in wet months and extend the period when water does not pass the diversion. The St. Louis Creek tributaries have not been individually studied, but streams below diversions with no bypass flows likely already have some channel narrowing and vegetative encroachment (refer to Section 4.6.3) and this likely would accelerate. The Proposed Action with RFFAs would have minor adverse cumulative impacts on the aquatic organisms in these streams. The impacts would be minor because any organisms that persist downstream of these diversions are tolerant of very low flows and because proposed changes are small in relation to historic diversions.

Most of the flows have already been previously diverted from these six St. Louis Creek tributaries and further threshold effects are unlikely as a result of the Proposed Action with RFFAs. These streams are already past an ecological tipping point. These streams currently have greater than 60% of their average annual flow removed, and although 60% of peak flows are not currently diverted in all year types, greater than 90% of flows are removed during the low-flow months. These streams do not currently support fish populations or many rheophilic macroinvertebrate species. As a result, no changes in fish populations are expected as a result of the Proposed Action with RFFAs. The relatively small increase in the number of zero flow days would further limit the amount of time when water flows past the diversion carrying with it drifting macroinvertebrates from upstream, and is available for colonization by macroinvertebrates downstream, or is available to augment flow increases from tributaries and groundwater further downstream. This could lead to a decrease in macroinvertebrate densities and may further restrict the presence of rheophilic species.

<u>*St. Louis Creek*</u>

In St. Louis Creek downstream of the Denver Water diversion (PACSM Node 2170), on an average annual basis there would be 20% less water in average years, 8% less water in dry years, and 14% less in wet years (refer to Appendix H, Table H-1.40). The additional diversions would occur during spring runoff. Peak flow would decrease by 12.5 cfs (23%) in average years (refer to Appendix H, Table H-14.4).

IHA analysis of upper St. Louis Creek shows that the Proposed Action with RFFAs would result in no reduction in minimum flows, likely because of the bypass flow in this stream. The frequency of high flows would not change, but the magnitude would increase slightly, and the duration would decrease slightly. The small and large floods would not experience appreciable decreases in magnitude, but their durations would decrease by 63% and 32%, respectively. The reductions in high flows would have a minor adverse impact on the section of St. Louis Creek just downstream of the diversion. Because of the lower spring flows, there may be changes to the macroinvertebrate community with fewer rheophilic species. Also, as noted above, the lower flows would further limit the water past the diversion carrying with it drifting macroinvertebrates from upstream and available for colonization by downstream, slightly decreasing connectivity to upstream populations. Almost all of the MMI scores for samples from St. Louis Creek were well above the threshold for attainment. The minor changes in the benthic invertebrate community with the Proposed Action with RFFAs likely would not affect MMI scores substantially and St. Louis Creek would continue to attain the aquatic life use.

In the lower section of St. Louis Creek, the differences in hydrology at near Fraser (PACSM Node 2200) with the Proposed Action with RFFAs indicate that runoff flows during May, June, and July would be reduced to create additional average diversions of 16% in average years, 3% in dry years, and 12% in wet years. The frequency of dry years would increase by approximately 50% (refer to Section 4.6.1).

PHABSIMs were available for lower St. Louis Creek from a site included in the Grand County Stream Management Plan (Grand County 2010). Changes in minimum and average habitat availability for brook trout would not exceed 2% under the Proposed Action with RFFAs in any year. Minimum habitat availability for brook trout occurs during peak runoff at this node, but model outputs indicate few changes to habitat availability during peak flows.

The increased frequency of dry years would result in greater habitat availability for brook trout adults. In dry years, the lower peak flows result in minimum habitat availability during the runoff period that is twice that in wet and median years. Average habitat availability in dry and median years is similar and approximately 10% higher than in wet years.

Water quality and water temperatures are not expected to change with the Proposed Action with RFFAs (refer to Section 4.6.2). The current sediment regime is also expected to be maintained annually (refer to Section 4.6.3). St. Louis Creek has minimum bypass flows in summer and winter. The reductions in flow would result in negligible cumulative impacts to aquatic resources under the Proposed Action with RFFAs in the lower section of St. Louis Creek.

Flow-related threshold effects are also not likely under the Proposed Action with RFFAs. Under Current Conditions, less than 60% of peak runoff and less than 60% of average annual flow are diverted in average and wet years and this stream has not crossed a tipping point. Additional diversions associated with the Proposed Action with RFFAs would not cross either threshold. In dry years, over 60% of peak flow is currently diverted, but 60% of the average annual flow is not.

King Creek

In King Creek (PACSM Node 2220), average annual flows downstream of the diversion would be reduced by 47% in average years and 25% in wet years with the additional diversions occurring throughout the year (refer to Appendix Table H-1.43). Average year peak flow in King Creek is already very low at 1.8 cfs and the Proposed Action with RFFAs would result in a further reduction of 0.7 cfs (39%) (refer to Appendix H, Table H-14.4). This tributary currently has no bypass flow requirements, and greater than 90% of the stream's native flow is diverted for eight months of the year. This stream does not support fish either upstream or downstream of the diversion but does support macroinvertebrates. The reductions in flow with the Proposed Action with RFFAs would not change winter flows but would reduce the flows that pass the diversion during wet months and extend the period when water does not pass the diversion by approximately two weeks on average (refer to Section 4.6.1). In some years there would be no additional diversions, but there would be up to 69 additional days with no flow past the diversion in one year.

IHA analysis (PACSM Node 2200) shows that the Proposed Action with RFFAs would result in no reduction in minimum flows, because of the extent of current diversions. The remaining spring runoff flows in King Creek would be reduced under the Proposed Action with RFFAs so that flows that would be high enough to meet the IHA high flow parameter would not occur annually. The occurrences and characteristics of high flows, small floods, and large floods would all decrease in duration but not in magnitude.

The flow reductions would have minor adverse cumulative impacts compared to existing conditions. This would further limit the amount of time available with flowing water past the diversion and available for macroinvertebrate production and to augment groundwater inputs downstream. King Creek is already severely diverted and may be near an ecological tipping point. Apparently, inputs of groundwater downstream of the diversion sustain a community of macroinvertebrates. No flow-based threshold effects are expected. However, a slightly longer no-flow period could lead to decreases in macroinvertebrate density, diversity, and number of Ephemeroptera, Plecoptera and Trichoptera (EPT) species and slight changes in species composition.

Elk Creek and Tributaries

PACSM Node 2300 includes West Elk Creek, West Fork Main Elk Creek, Main Elk Creek, and East Elk Creek (refer to Appendix Table H-1.39). The additional diversions with the Proposed Action with RFFAs would reduce flows by 32% in average years and 23% in wet years on an average annual basis with no additional diversions in dry years. Average year peak flows would decrease by 33% (refer to Appendix H, Table H-14.4). These four streams have no bypass flows and flows that pass the diversion would occur approximately 10 days (refer to Section 4.6.1). In most years, there would be one week or less of additional days with no flow past the diversion; however, additional days would range up to 31 days in one year.

IHA analysis of Elk Creek and its tributaries shows that the Proposed Action with RFFAs would result in no reduction in minimum flows, because these tributaries are currently 100% diverted for much of the year. High flows, small floods, and large floods would all decrease in duration from 33 to 88%. Flows that would be high enough to meet the IHA high flow parameter would not occur annually under the Proposed Action with RFFAs, but the frequency of small and large floods would not change.

Three of these tributaries are severely diverted and past ecological tipping points: West Fork Main Elk, Main Elk, and East Elk creeks. As a result, no flow-based threshold effects are expected for these three tributaries. The reductions in flow with the Proposed Action with RFFAs would result in minor cumulative impacts that would reduce connectivity to upstream macroinvertebrate populations and further limit the water available to augment groundwater inputs downstream.

West Elk Creek contained populations of fish and invertebrates downstream of the diversion. This stream is mildly diverted and likely not past an ecological tipping point. Although an average of 60% of peak flows is not currently removed from these streams, they are nearly 100% diverted for seven months of the year. The Proposed Action with RFFAs would increase depletions compared to native flow by 71% on average, and by 66% of peak flow. The reductions in flow with the Proposed Action with RFFAs would result in minor adverse cumulative impacts compared to Current Conditions. There could be minor reductions in fish and/or invertebrate populations downstream of the diversions. The reductions in flow in this stream may be sufficient to cross an ecological tipping point.

MMI samples from Main Elk Creek indicate that it sometimes does not score above the threshold for attainment of the aquatic life use. The reductions in flow with the Proposed Action with RFFAs may increase the likelihood that MMI scores would be below the threshold.

Vasquez Creek

In Vasquez Creek below the Denver Water diversion (PACSM Node 2280), proposed flow reductions would be 31% in average years, 5% in dry years, and 22% in wet years with RFFAs and the Proposed Action (refer to Appendix Table H-1.35). In average and wet years, the greatest flow changes would occur in May, and in dry years, the greatest flow changes would occur in June and July. Peak flow would decrease by nearly 26 cfs (36%) in average years (refer to Appendix H, Table H-14.4). There is a seasonal bypass flow requirement of 8 cfs in summer and 3 cfs in winter downstream of the diversion. The number of days when the flow would be reduced to the minimum bypass would increase by approximately two weeks on average.

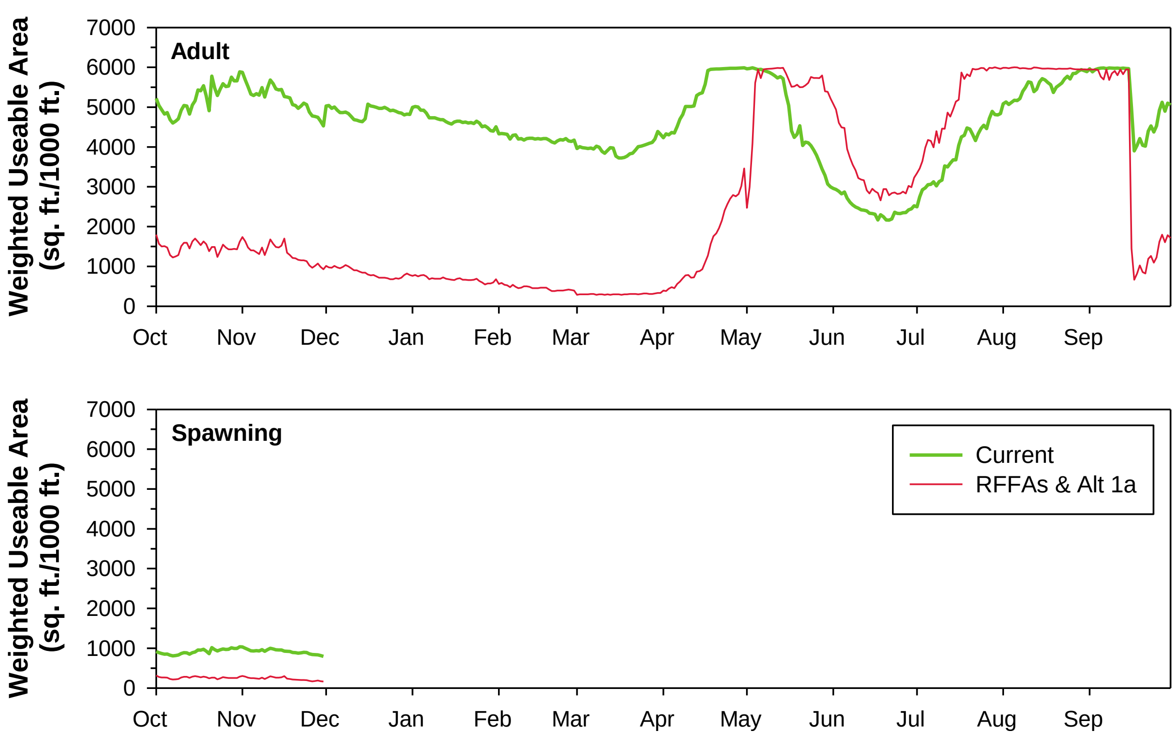
Farther downstream at PACSM Node 2370, the Proposed Action with RFFAs would result in lower flows in the runoff period compared to existing conditions. Annual flows would be 53% lower in average years, 67% lower in dry years, and 34% lower in wet years. Increased flow diversions would be greatest during spring runoff months, but flow depletions in individual months would be as much as 92% (refer to Appendix

Table H-1.37). The frequency of dry years would also increase substantially (refer to Section 4.6.1).

IHA analysis results for Vasquez Creek below the Denver Water diversion (PACSM Node 2280) show that the Proposed Action with RFFAs would result in no reduction in minimum flows, likely due to the bypass flow. The high flow frequency would decrease from 1 to 0 per year (i.e., flows that meet the high flow threshold would not occur annually). The durations of high flows, small floods, and large floods would be reduced by 42 to 71% but the frequency would not change.

PHABSIM habitat relationships were available for the adult and spawning life stages of brook trout in Vasquez Creek. Minimum habitat availability occurs during the lowest flows of the year in March for adult brook trout in Vasquez Creek (Figure 4.6.11-6), and habitat availability increases during spring runoff. In median years, minimum habitat availability would decrease by 87% for adult brook trout due to substantially reduced winter flows, and for spawning habitat would decrease by 80%. In dry years, minimum adult and spawning habitat availability would decrease by 93% and 94%, respectively, and in wet years, adult and spawning habitat would decrease by 90% and 65%, respectively. Average habitat availability would also decrease 37 to 55 for adults and by 35 to 84% for spawn brook trout. Changes in habitat availability are greatest during the months where habitat is already limited under Current Conditions.

Figure 4.6.11-6
WUA for Spawning and Adult Brook Trout in Vasquez Creek in a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



The Full Use of the Existing System and the Proposed Action with RFFAs would increase the frequency of dry years. Minimum habitat availability for brook trout adults in dry years is 30% lower than in median years but 22% higher than in wet years. However, average habitat availability in dry years is 14% and 21% lower than in median and wet years, respectively.

No long-term changes in sedimentation or channel morphology are expected in Vasquez Creek (refer to Section 4.6.3). Changes in temperature or other water quality parameters are also not expected as a result of the Proposed Action with RFFAs (refer to Section 4.6.2). The lower runoff flows could tend to provide more favorable habitat for invertebrates in average and wet years. However, the large magnitude of flow changes, especially in the lower reaches of Vasquez Creek, would change the species composition of the benthic invertebrate community and may be low enough to exclude some rheophilic species.

The reduced flows, greater frequency of dry years, and resulting decreases in brook trout habitat availability and macroinvertebrate community changes would have a moderate adverse impact on aquatic resources in Vasquez Creek. The proposed additional diversions would probably result in a cumulative reduction in brook trout densities. The decrease in wetted area associated with the increased diversions would probably lead to smaller macroinvertebrate populations likely with fewer EPT species and lower diversity. Recent MMI scores for Vasquez Creek were below the threshold for attainment and it is provisionally on the Section 303(d) List. The reductions in flows indicate that future scores would likely be below the threshold for attainment. Flow depletion information from Vasquez Creek at the Denver Water diversion suggests that this stream is very close to the 60% depletion thresholds of Carlisle et al. (2010) and Baran et al. (1995) and would cross these thresholds with the Proposed Action with RFFAs. The stream would still maintain populations of fish and invertebrates but would likely cross an ecological tipping point.

Little Vasquez Creek

In Little Vasquez Creek (PACSM Node 2340), average annual flow would be 67% lower in average years, 54% lower in wet years, and 5% lower in dry years (refer to Appendix Table H-1.36). The additional diversions would occur throughout the year but mostly in the wet months. This stream has no bypass flow requirement although there is a 0.5 cfs bypass agreement. Flow depletions from native flows with the Proposed Action with RFFAs would be 90% lower for average annual flows and for peak flows. There is very low flow downstream of the diversion through the winter with Current Conditions but this stream supports fish and invertebrates downstream of the diversion. The Proposed Action with RFFAs would reduce the flows that pass the diversion in wet months, extend the period when little flow passes the diversion by one to two weeks on average, and have minor adverse cumulative impacts on aquatic resources in Little Vasquez Creek.

An increase in the number of low flow days could cause further declines in fish densities downstream of the diversion. Fish densities in Little Vasquez Creek have been lower than the regional average since 1992, probably because of low flows. It is likely that they will remain low or decrease further as a result of increased water diversion. Flow-based threshold effects are possible on Little Vasquez Creek because it is already near a tipping point.

Cooper Creek

Additional diversions on Cooper Creek would result in 42% lower flow in average years and 52% in wet years at PACSM Node 2380 on an average annual basis (refer to Appendix H-1.32). The diversions would mostly reduce flows during runoff and extend the period with no flow past the diversion by one week on average. There is no bypass flow for this stream and it is fully diverted most of the time with low or no flow through the stressful winter period. The additional diversions during wet months would have minor adverse cumulative impacts for the Proposed Action with RFFAs compared to Current Conditions. Because Cooper Creek has little remaining native flow and does not support fish, flow-based threshold effects are not likely under the Proposed Action with RFFAs; it is likely already past an ecological tipping point. Reductions in macroinvertebrate densities and changes in species composition are possible under the Proposed Action with RFFAs, given that the number of zero flow days would increase slightly and further limit the water and time available to support macroinvertebrates.

Jim Creek

The additional diversions in Jim Creek under the Proposed Action with RFFAs would result in 57% less water in average years and 37% in wet years (PACSM Node 2160) on an average annual basis (refer to Appendix Table H-1.30). The additional diversions would occur primarily in May and June but could occur throughout the year. Peak flows would be reduced by 7 cfs (48%) in average years (refer to Appendix H, Table H-14.4). There is no bypass flow for Jim Creek and it is fully diverted much of the year, and this would be extended by approximately one week or less in the majority of years but up to three weeks more in a few years. Jim Creek supports fish in the short section downstream of the diversion and likely has not crossed a tipping point. There are inputs of water a short distance downstream of the diversion. This stream has very low or no flow through the winter just below the diversion, which probably represents the most stressful period for aquatic organisms.

IHA analysis results from PACSM Node 2160 show that minimum flows would be unaffected because the stream is often dry under Current Conditions. The Proposed Action with RFFAs would not change the magnitude but would decrease the duration of small floods and large floods by 37% and 45%, respectively, when they occurred.

The lower flows in wet months would allow more sediment to accumulate in the channel downstream of the diversion and allow accelerated vegetative encroachment of the stream channel (refer to Section 4.6.3). The additional diversions in wet months and the extension of the time of full diversion with the Proposed Action with RFFAs would have minor adverse cumulative impacts on aquatic resources. Additional flow-based threshold effects are unlikely in Jim Creek, given that it is 100% diverted five months of the year with 89% of the average annual flow already diverted, and there are inputs of groundwater a short distance downstream of the diversion. However, an increase in zero flow days could cause a decrease in fish and macroinvertebrate densities. There may be some changes in species composition that would result in fewer EPT and rheophilic species.

North Fork Ranch and Dribble Creeks

Downstream of the Denver Water diversions on the North Fork Ranch Creek and Dribble Creek (PACSM Node 2490), the Proposed Action with RFFAs would result in 27% lower flow in average years and 17% in dry years and 14% in wet years on an average annual basis (refer to Appendix Table H-1.46). Additional diversions would be greatest during spring runoff, but additional diversions would also occur during low flows. Average annual peak flows would be reduced by nearly 3 cfs (15%) (refer to Appendix H, Table H-14.4). These two streams have no bypass flows, are fully diverted for much of the year, and are past ecological tipping points. North Fork Ranch Creek supports fish and macroinvertebrates farther downstream of the diversion because of inputs of groundwater.

IHA analysis of PACSM Node 2490 shows that minimum flows would not be reduced, given the extent of current diversions. The timing and frequency of high flows would not change significantly, but duration would decrease by 20%. The magnitude and timing of small and large floods would not change with the Proposed Action with RFFAs, but the duration of both would decrease by 42% and 63%, respectively.

These streams have all of their flows diverted for much of the year. Additional diversions during the wet months would extend the dry period by two weeks on average and up to several weeks in some years (refer to Section 4.6.1). Additional diversions during peak runoff would reduce the size of the snowmelt peak. However, because both of these streams are already severely diverted and past tipping points, no flow-based threshold effects are expected as a result of the Proposed Action with RFFAs. Reductions in flow of this magnitude would have a minor adverse impact on the fish and invertebrate communities in North Fork Ranch Creek and on macroinvertebrates in Dribble Creek. Fish densities would likely not change appreciably, but an increase in the number of zero flow days may cause a decrease in macroinvertebrate densities.

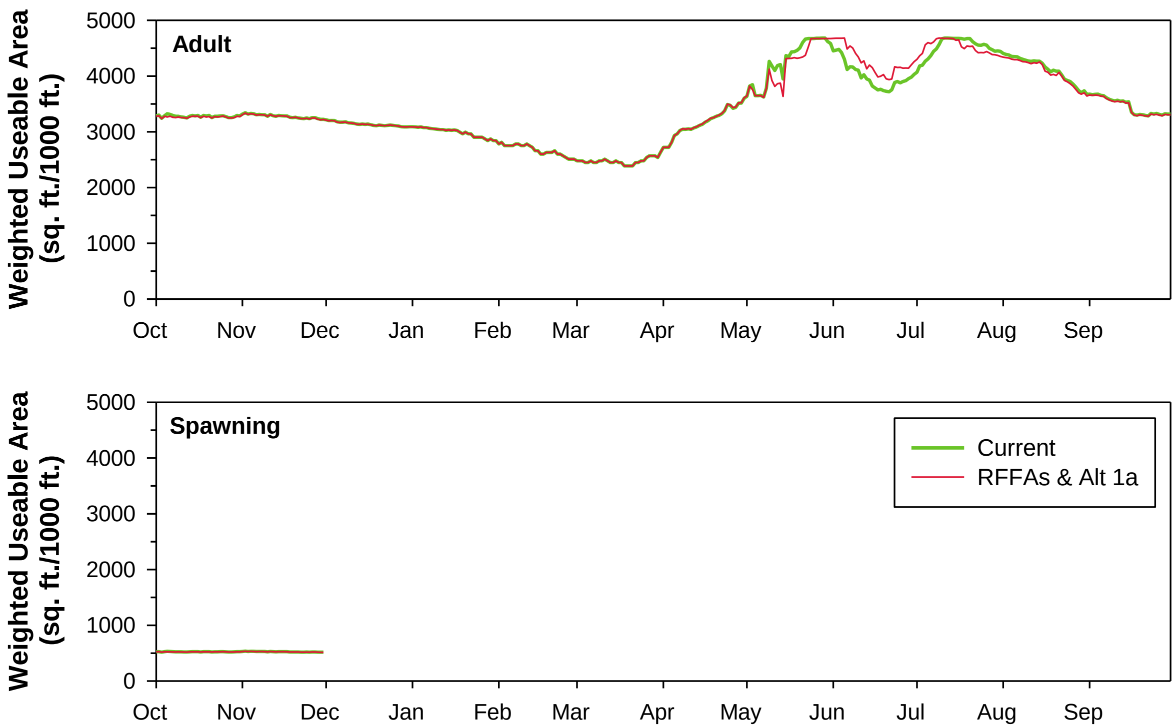
Main Ranch Creek

At Ranch Creek PACSM Node 2500 downstream of the Denver Water diversion, there would be 16% less water in average years, 6% less water in dry years, and 9% less water in wet years with the Proposed Action with RFFAs (refer to Appendix Table H-1.47). The majority of the water would be diverted during spring runoff. Peak flows would be reduced by 4 cfs (17%) in average years (refer to Appendix H, Table H-14.4). There would be no increase in the frequency of dry years (refer to EIS Section 4.6.1). The flow in this section of Ranch Creek is very low in the winter months, near 1 cfs although there is a 2 cfs winter bypass flow requirement.

IHA analysis results from PACSM Node 2500 show that minimum flows would not be affected by RFFAs and the Proposed Action, due to the bypass flow requirement. High flows would continue to occur under the Proposed Action with RFFAs; the timing, magnitude, frequency, and duration would remain similar. The duration would decrease for small and large floods by 39% and 61%, but the magnitude and timing would remain unaffected.

A PHABSIM for brook trout was available for Ranch Creek. Minimum habitat availability for adult brook trout occurs in March and April at the lowest flows of the year, and availability is highest during spring runoff in median, wet, and dry years. Flows proposed under the Proposed Action with RFFAs do not produce any appreciable changes in minimum or average habitat availability for adult or spawning brook trout in median, dry, or wet years (Figure 4.6.11-7). The low flows in winter are probably the critical low habitat period in this stream for fish and probably also for invertebrates. The similar flows in these months with the Proposed Action with RFFAs and Current Conditions (2006) indicate that minimum habitat availability in winter would not change.

Figure 4.6.11-7
WUA for Spawning and Adult Brook Trout in Ranch Creek for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



Long-term sediment dynamics are not expected to change under the Proposed Action with RFFAs (refer to Section 4.6.3). Settlement transport capacity and supply will be reduced with the predicted flow changes. Additional sediment deposition may occur in localized areas but deposition is expected to be limited in duration. Flows sufficient to mobilize sediment and maintain existing stream characteristics are predicted to remain. Ranch Creek commonly has exceedances of temperature criteria in late summer at low flows. Late summer low flows are not expected to change appreciably and high water temperatures would not change appreciably (refer to Section 4.6.2). Main Ranch Creek consistently supports fish in the lower sections due to inputs of groundwater and has not crossed a tipping point. Although the depletion threshold of Baran et al. (1995) is not met, the threshold of Carlisle et al. (2010) is approached in dry years. However, the Proposed Action with RFFAs would not change flows enough in average or wet years to produce flow-based threshold effects.

The Proposed Action with RFFAs would reduce flows below the diversion in wet months. This would extend the period of low flows in the stream by over one week on average. The Proposed Action with RFFAs would have a minor adverse impact on the fish and invertebrate communities of Ranch Creek. MMI scores for samples from Ranch Creek were well above the threshold for attainment and this is not likely to change with the Proposed Action with RFFAs.

Middle Fork and South Fork Ranch Creek

These streams are fully diverted at times and there are no bypass requirements. The additional diversions with the Proposed Action with RFFAs would result in 39% lower flows in average years and 18% lower flows in wet years (PACSM Node 2520) on an average annual basis (refer to Appendix Table H-1.48) with no changes in dry years. Peak flows would be reduced by 10 cfs (30%) in average years (refer to Appendix H, Table H-14.4). These streams have very low or no flow through the winter, which probably represents the most stressful period for aquatic organisms.

IHA analysis of PACSM Node 2520 shows that decreases in minimum flows characteristics would not be affected, given the extent of current diversions, but zero flow days would increase slightly. The magnitude, duration, and timing of high flows would not be affected by the Proposed Action with RFFAs. However, the duration of small and large floods would decrease by 49% and 74%, respectively.

The Proposed Action with RFFAs would not change flows in the winter in most years but the reduced flows past the diversions in wet months and the extension of the period when the streams are fully diverted by approximately two weeks on average (refer to Section 4.6.1) would have minor adverse cumulative impacts in these two streams. Flow-based threshold effects are not expected with the Proposed Action with RFFAs because these streams are already severely diverted and past tipping points. A minor decrease in macroinvertebrate densities is possible with the Proposed Action with RFFAs.

Wolverine Creek

There is no PACSM node for Wolverine Creek. We assume that more water would be diverted during the wet months similar to nearby streams. This very small stream has no bypass flow and is fully diverted much of the year with low or no flow through the winter. The additional diversions during the wet months with the Proposed Action with RFFAs would have minor adverse cumulative impacts compared to Current Conditions. Flow-based threshold effects are not anticipated as a result of the Proposed Action with RFFAs because this stream is already severely diverted and past a tipping point. Minor cumulative decreases in macroinvertebrate densities may occur as a result of a small increase in the number of zero flow days.

Cub and Buck Creeks

Additional diversions on Cub Creek and Buck Creek would reduce flows by 36% in average years and 33% in wet years (PACSM Node 2540) on an average annual basis primarily in May, June, and July with no additional diversions in dry years (refer to Appendix Table H-1.31). These two small streams have no bypass flow and are fully diverted much of the year, which would be extended for about a week on average, with low or no flow through the winter. The additional diversions during the wet months with the Proposed Action with RFFAs would have minor adverse cumulative impacts compared to Current Conditions. Flow-based threshold effects are not anticipated as a result of the Proposed Action with RFFAs because these streams are already severely diverted and past tipping points. Minor decreases in macroinvertebrate densities may occur as a result of a small increase in the number of zero flow days.

Englewood Ranch Gravity System

The Englewood Ranch Gravity System includes diversions on Meadow, South Trail, North Trail, Hurd, Hamilton, Cabin, and Little Cabin creeks. The diversions on South and North Trail creeks also affect flows in Trail Creek. PACSM Node 2480 (refer to Appendix Table H-1.45) models flow in these streams. With the Proposed Action with RFFAs, changes in average annual flow would be 4% in average years and 5% in wet years with no changes in dry years on an average annual basis. The additional diversions would occur during spring runoff. The small changes in flow with the Proposed Action with RFFAs would have negligible cumulative impacts on fish and invertebrates in these streams. Current diversions on these streams do not approach any flow-based thresholds for population-level effects, and diversions under the Proposed Action with RFFAs would be 22% of average annual flow and be 14% in peak flow months, and would not be sufficient to cross these thresholds. Therefore, no flow-based threshold effects are expected for these streams under the Proposed Action with RFFAs.

Fraser River Watershed Level Effects

Additional diversions of spring flows with the Proposed Action with RFFAs would decrease flows past the diversions in many of the tributary streams in the Fraser River watershed. Under Current Conditions (2006), the tributaries in the watershed have already been affected by the diversions included in the Project area as well as by many other diversions not part of the Project. These streams have also been affected by other watershed-scale activities including development, and the establishment and maintenance of roads and culverts. These activities have altered some ecological processes, especially connectivity of upstream and downstream sections of stream, including transfer of nutrients and sediment transport. The Proposed Action would not add any new diversions or roads and would not change the existing patterns of connectivity. However, the reductions in the number of days when water passes the diversions would reduce to some extent the transport of fish, benthic invertebrates, nutrients, and sediment from upstream to downstream sections, which would be a minor adverse effect.

Williams Fork River

Headwaters to the South Fork

The Williams Fork River upstream of the South Fork was evaluated with PHABSIM. Hydrology data from the Williams Fork above Darling Creek gage (PACSM Node 3600) were used to simulate habitat for adult and spawning life stages of brook trout. The hydrology data for the Proposed Action with RFFAs indicate average annual flow reductions of 13% in average and dry years and 6% in wet years. Peak flow in an average year would be reduced by 17 cfs (9%) (refer to Appendix H, Table H-14.4). Additional diversions would occur from May through August, and relative reductions would be largest in July of dry years. The Proposed Action, Full Use of the Existing System, and other RFFAs would increase the frequency and duration of dry years in the Williams Fork River and tributaries (refer to Section 4.6.1). The timing of the seasonal pattern of spring runoff would not change substantially although the magnitude and duration would be reduced in some years.

IHA analysis of flow at PACSM Node 3600 showed that 90-day minimum flows would decrease by 2%. Changes to high flow, small flood, and large flood IHA parameters would also be minor (i.e., 7% or less).

No changes in sediment cycling or channel morphology are expected with the Proposed Action with RFFAs (refer to Section 4.6.3). No substantial changes to water quality are expected with the Proposed Action with RFFAs (refer to Section 4.6.2).

The pattern of habitat availability for adult brook trout in Segment 1 of the Williams Fork River indicates minimum habitat during runoff in median, wet, and dry years. The reductions in runoff flows with the Proposed Action with RFFAs may decrease stressful conditions for brook trout, but minimum and average adult brook trout habitat availability would experience minor changes (1% or less) under the Proposed Action with RFFAs. Changes in spawning habitat would also be small: minimum and average spawning habitat availability would decrease by 5% in median years; no changes are expected in dry or wet years. The increased frequency of dry years would increase habitat availability for brook trout. In dry years, minimum habitat availability is 60% and 130% higher than in median and wet years, respectively, due to lower spring runoff flows. Average habitat availability for brook trout adults in dry years is 11% higher than in wet years.

For aquatic resources, the small differences in flow for the Proposed Action with RFFAs would have negligible cumulative impacts compared to Current Conditions. MMI samples from the Williams Fork River indicated attainment and the changes in flow are not expected to affect MMI scores. Because the current flow depletions from this stream do not approach either of the flow-based thresholds, and because additional proposed diversions are small, no flow-related threshold effects are expected with the Proposed Action with RFFAs.

South Fork to Colorado River

Downstream of the South Fork, reductions in flow with the Proposed Action with RFFAs would be minor in the Williams Fork River. Near the Leal gage (PACSM Node 3750), average annual flow reductions would be 4% or less in all year types. Most of the additional diversions would be during runoff flow months. Reductions of this magnitude would have negligible cumulative impacts on aquatic resources in this section of the Williams Fork River.

Williams Fork Tributaries

The Proposed Action with RFFAs would include additional diversions of water from McQueary, Jones, Bobtail, and Steelman creeks, which form the headwaters of the Williams Fork River (PACSM Nodes 3100, 3150, 3200, and 3250). For these four streams the additional diversions would be up to 37% in average years, 89% in dry years, and 14% in wet years (refer to Appendix Tables H-1.52 through H-1.55). Most of the water would be diverted during spring runoff. Peak flow in Bobtail Creek would be reduced by over 8 cfs (17%) in average years (refer to Appendix H, Table H-14.4). There would be increased frequency of dry years (refer to Section 4.6.1). There are no bypass flows in these streams and they are fully diverted for much of the year. The additional diversions would extend the period of no flow past the diversions by approximately one month in these four streams. The hydrology data for the Williams Fork River at a point just downstream of these four tributaries (PACSM Node 3300) indicate the additional diversions would result in 29% less water in average years, 58% less water in dry years, and 11% less water in wet years (refer to Appendix Table H-1.56). The timing of the seasonal pattern of spring runoff when flows bypass the diversions would not change substantially although the magnitude and duration would be reduced in some years.

IHA analysis results for Bobtail Creek (PACSM Node 3150) show that 90-day minimum flows would not be reduced, given the extent of current diversions. With the Proposed Action with RFFAs, the high flow parameter would increase in magnitude and occur 18 days earlier than under Current Conditions; the duration would not change. Small and large floods would not change with respect to magnitude or timing, but durations would decrease by 44% and 51%, respectively. Similar flow changes may occur in the other three tributaries.

Downstream of the Denver Water diversions on McQueary, Bobtail, and Steelman creeks, brook trout are the dominant fish species. Data were not available for Jones Creek, but this stream may also contain brook trout. Habitat simulation data are not available for these streams. R-2-Cross data for Bobtail Creek indicate that flows less than 1 cfs would not be sufficient to fully maintain fish and invertebrates and this is probably true for the other tributaries. The low flows in winter in all four streams at a point downstream of their diversions are less than 1 cfs with Current Conditions and are probably the most stressful period for the aquatic resources of these tributaries. However, similar to the Fraser River tributaries, these streams resume flow downstream of the diversions from groundwater, tributaries, and wetlands during times when they are fully diverted.

The flow reductions during runoff with the Proposed Action with RFFAs would have minor adverse cumulative impacts on the fish and invertebrate populations in McQueary, Jones, Bobtail, and Steelman creeks. Although there would be no change in the critical winter flows as there is already no flow past the diversion in winter, the Proposed Action with RFFAs would reduce the flow passing the diversions in wet months and extend the period when these streams are fully diverted limiting the temporary use of some sections of stream by aquatic organisms and reducing the contributions of water to the gaining sections of stream. Because all of these streams are already severely diverted, no flow-based threshold effects are expected as a result of the Proposed Action with RFFAs. The increase in zero flow days could reduce fish and macroinvertebrate populations downstream of the diversions.

Williams Fork Reservoir

The seasonal pattern of filling and draining in Williams Fork Reservoir would be similar with Current Conditions (2006) and with Full Use with a Project Alternative and RFFAs (2032). However, drawdowns would be less severe with the Proposed Action with RFFAs (refer to Section 4.6.2). In most years, the reservoir would not be drawn down as much. This would allow for a greater volume of water available to sustain fish and other organisms and would have minor beneficial cumulative impacts under the Proposed Action.

Colorado River

Hydrology data for two segments of the Colorado River were used to model habitat availability for brown and rainbow trout. Hydrology data from Colorado River at Windy Gap Reservoir (PACSM Node 1350), Colorado River upstream of Hot Sulphur Springs (PACSM Node 1400), and Colorado River downstream of Hot Sulphur Springs (PACSM Node 1425) were used in Segment 1 of the river. Hydrology data for the Colorado River at the Williams Fork confluence (PACSM Node 1430) and the Colorado River at Kremmling (PACSM Node 5020) were used in Segment 2. There are two or three sets of PHABSIM habitat relationships for brown and rainbow trout in each of the two segments of the river. The Proposed Action with RFFAs would result in reductions in flow during the runoff period compared to Current Conditions (refer to Appendix Tables H-1.58, H-1.59, and H-1.60). The timing of the seasonal pattern of spring runoff would not change substantially although the magnitude and duration would be reduced in some years. The Proposed Action, Full Use of the Existing System, and other RFFAs would increase the frequency and duration of dry years in the Colorado River (refer to EIS Section 4.6.1).

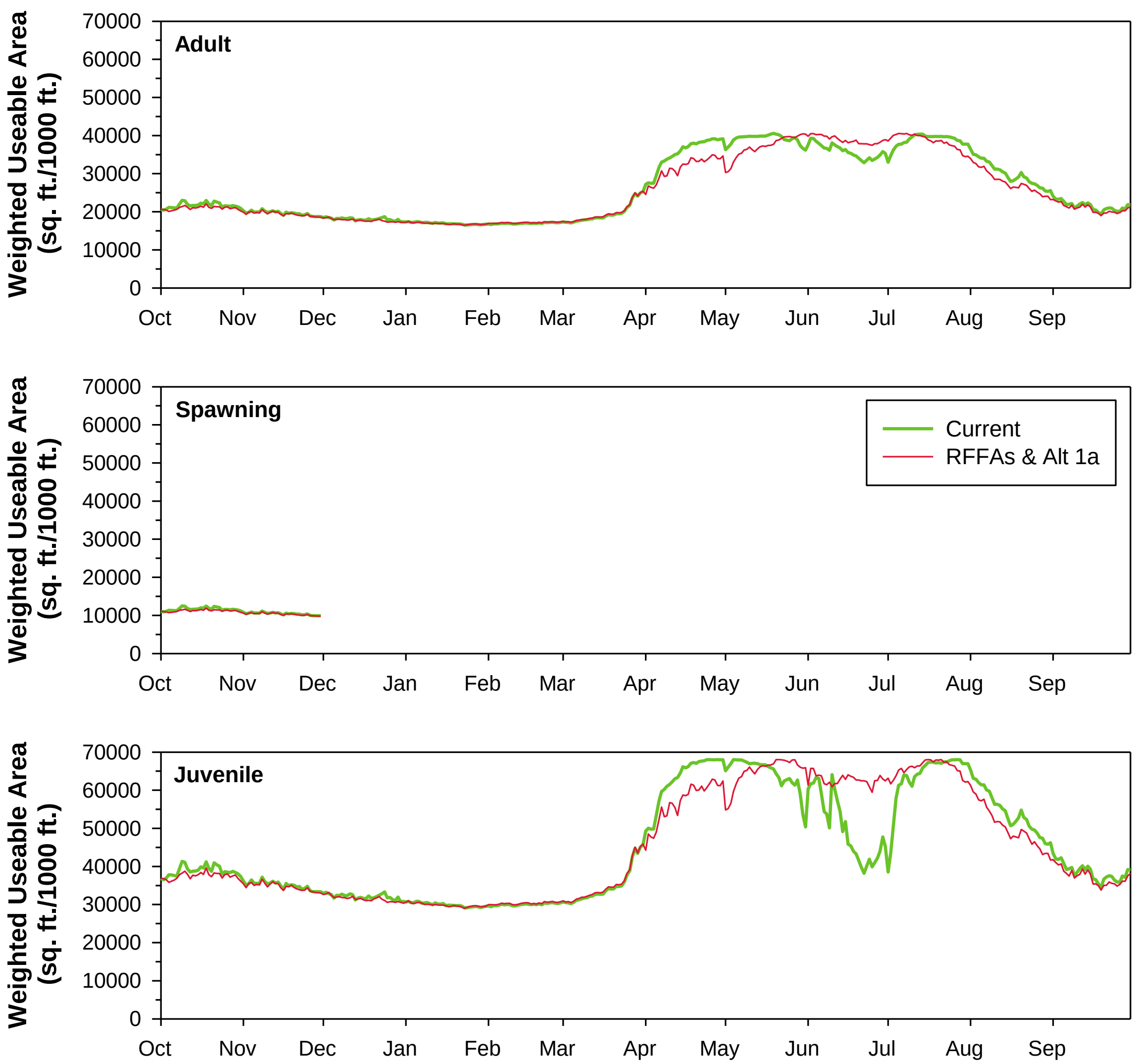
There would be no long-term increase in sediment deposition with the Proposed Action with RFFAs. Flushing flows would be sufficient throughout the two segments of the Colorado River. Therefore, there would be no long-term increase in habitat for the *T. tubifex* that carry whirling disease. Water temperatures are expected to be similar to Current Conditions on most days. Overall, the Proposed Action with RFFAs would not have an effect on whirling disease in the Colorado River. The adequate flushing flows and the similarity in baseflows in late summer and in the sediment transport capabilities of the Colorado River indicate that the Proposed Action with RFFAs would also have no effect on Didymo. The Proposed Action with RFFAs would not change the current system of diversions and canals and would not introduce any new pathways for nuisance species distribution.

Segment 1, Windy Gap Reservoir to Williams Fork River

Hydrology data from Colorado River at Windy Gap Reservoir (PACSM Node 1350), Colorado River upstream of Hot Sulphur Springs (PACSM Node 1400), and Colorado River downstream of Hot Sulphur Springs (PACSM Node 1425) for the Proposed Action with RFFAs indicate average annual flow reductions of 18% in average and dry years and 13% in wet years (refer to Appendix Table H-1.58). The additional reductions would occur from April through August, and reductions would be largest in June of wet years. Peak flow reductions would be 176 cfs (22%) in average years (refer to Appendix H, Table H-14.4). The frequency of dry years would nearly double (refer to Section 4.6.1). The hydrology data were used to simulate habitat for life stages of brown and rainbow trout. Three sets of WUA curves were available for Segment 1 of the Colorado River. The curves at the Chimney Rock Site are from the Grand County Stream Management Plan (2010). The two sets of curves at the Lone Buck Site were generated by CPW and by Miller Ecological Consultants, Inc.

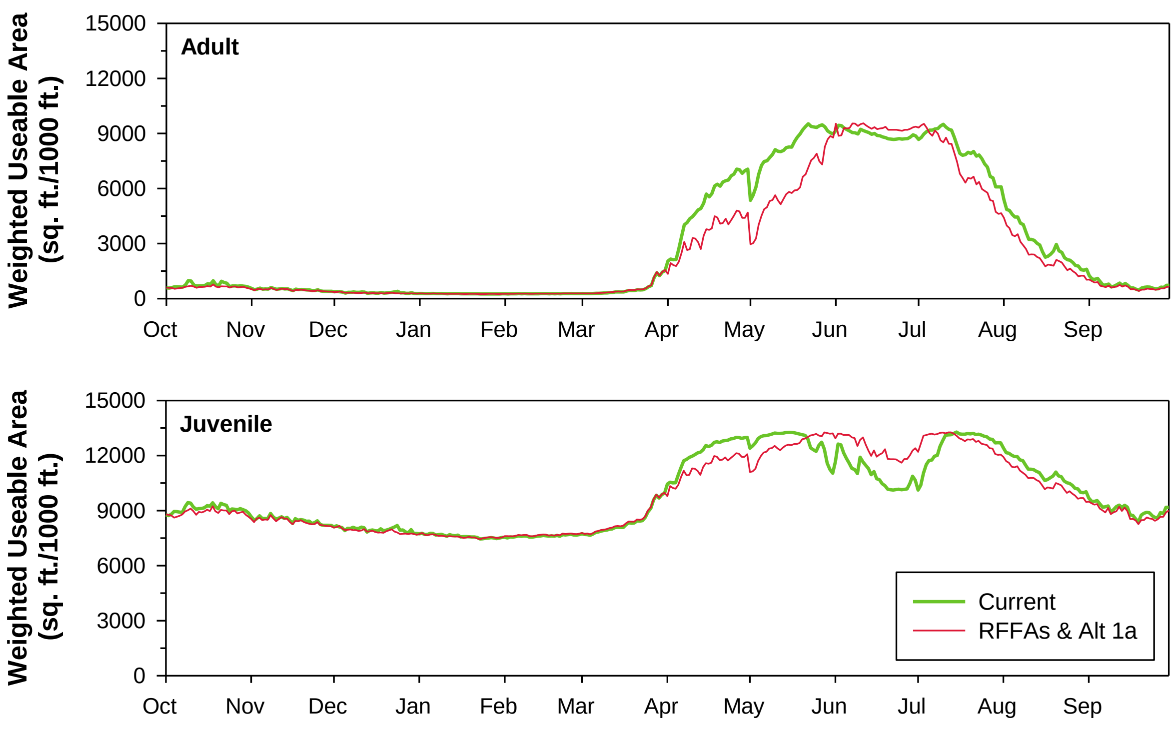
Habitat availability time series analyses from all three curves suggest that there would be minor changes in WUA for brown trout under the Proposed Action with RFFAs (Figure 4.6.11-8). Minimum habitat availability changes would usually be less than 1% and would not exceed 7% in almost all cases. Time series analyses using the Chimney Rock curves suggested that minimum WUA for brown trout would increase by 34% for adults and by 32% for juveniles in median years. Changes in average WUA would not be more than 5% in any year type for any life stage. This suggests that flow reductions from the Project with RFFAs would not have much effect for brown trout.

Figure 4.6.11-8
WUA for Three Life Stages of Brown Trout in Segment 1 of the Colorado River (CPW-Lone Buck Site) for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



Most changes to habitat availability for rainbow trout with the Proposed Action with RFFAs would be 7% or less. This indicates that the Proposed Action with RFFAs would cause little change in habitat for rainbow trout (Figure 4.6.11-9). There would be a few larger changes in some year types for some life stages. Time series analyses at all three sites predicted increases in minimum or average habitat availability for spawning and juvenile rainbow trout of 11% to 26%. Two of the time series analyses predicted minor habitat losses of 10% to 15% for adult rainbow trout. Because pre swim-up and juvenile life stages tend to be more sensitive to habitat changes than adults (Belica 2007; Bernstein and Montgomery 2008; Nehring and Anderson 1993), the increases in habitat availability for early life stages may offset minor losses in adult WUA. Rainbow trout currently account for a small portion of the fish community compared to brown trout. However, if whirling disease-resistant rainbow trout begin to more successfully reproduce in the Colorado River, these changes in habitat availability may become more important.

Figure 4.6.11-9
WUA for Two Life Stages of Rainbow Trout in Segment 1 of the Colorado River (Miller-Lone Buck Site) for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



The increased frequency of dry years would result in a variety of increases and decreases in trout habitat availability based on the relationships at the three sites. In many cases, habitat availability for juvenile brown and rainbow trout would be higher with the reduced runoff flows in dry years while the lower flows would reduce average and minimum habitat availability for adult trout.

No quantitative habitat information is available for sculpin or *P californica*. Nehring (2010) suggests that declines of sculpins and salmonflies in the Colorado River downstream of Windy Gap Reservoir are related to decreased flows. If there is a causal link between lower flows and sculpin and salmonfly declines, the Proposed Action with RFFAs could cause the declines to continue.

No significant changes in sediment cycles or channel morphology are expected as a result of the Proposed Action with RFFAs (refer to Section 4.6.3). Water temperatures are already of concern in Segment 1 of the Colorado River and the cumulative effects of the Proposed Action with RFFAs would be moderate (refer to Section 4.6.2). There have been a number of exceedances for daily maximum and maximum weekly average temperature (MWAT) standards at multiple sites in this segment of the Colorado River between 2005 and 2010. Temperature exceedances only occurred on hot days when flows were 125 cfs or less, and the number of days during which flows are 125 cfs or less are expected to increase under the Proposed Action with RFFAs. However, water temperature is determined more by air temperature than by low flows, as discussed in more detail in Section 4.6.2, and no increase in the frequency of water temperature exceedances is expected.

Habitat availability analyses indicate that the Proposed Action with RFFAs would have minor cumulative effects on brown and rainbow trout in Segment 1 of the Colorado River. Most of the changes in habitat would be minor and most of the larger changes would result in higher habitat availability. There would also be minor cumulative changes in channel morphology and water temperatures. As a result, the Proposed Action with RFFAs would have negligible cumulative impacts on aquatic resources in Segment 1 of the Colorado River. A portion of this segment of the river is on the Monitoring and Evaluation List for low MMI scores. The changes with the Proposed Action with RFFAs would not likely affect MMI scores.

Because the current average annual flow depletions from this stream are estimated to be 66%, Segment 1 of the Colorado River is near a flow-based threshold. The minimal changes to habitat availability, channel morphology, and water temperatures indicate that the Proposed Action with RFFAs would not cause this segment of the Colorado River to cross an ecological tipping point.

Segment 2, Williams Fork River to Blue River

Changes in the annual hydrology of the Colorado River for the Proposed Action with RFFAs in the Colorado River at the Williams Fork confluence (PACSM Node 1430), would be 8% less in average years and 7% less in wet years (refer to Appendix Table H-1.59). In dry years flows would be 6% greater. Monthly depletions would primarily occur from April through June and would be greatest in May of wet years at 27%. Changes in the Colorado River at Kremmling (PACSM Node 5020) would be similar: flows would be 9% less in average years, 1% less in dry years, and 7% less in wet years (refer to Appendix Table H-1.60). Additional diversions would be greatest in June of average years at 18%, and similar percentages would be diverted in April and May of wet years. Peak flows at these two nodes would be reduced by 15% and 22% in average years (refer to Appendix H, Table H-14.4).

Three sets of PHABSIM curves were developed for multiple life stages of brown trout and rainbow trout for this segment: A site at the Kemp-Breeze State Wildlife Area was developed by Miller Ecological Consultants, Inc. Sites above and below the Kemp-Breeze Ditch were provided in the Grand County Stream Management Plan (Grand County 2010)

Time series analyses of trout habitat availability from the Kemp-Breeze Site curves show no appreciable change in minimum or average WUA in any year type for brown trout. All of the changes in habitat availability would be 2% or less. The habitat availability time series using the above Kemp-Breeze Ditch Site results in an increase in minimum adult habitat availability of 31% and juvenile habitat availability of 29% in median years and an

11% decrease in minimum juvenile WUA in dry years. No other changes in for minimum habitat availability in dry years or in for other life stages would be more than 4% in any year type. Using the below Kemp-Breeze Ditch Site information, the time series shows changes of less than 4% except for a 33% increase in minimum juvenile habitat availability in median years. No changes to average brown trout habitat availability would occur with the Proposed Action with RFFAs. PHABSIM results indicate that average WUA would remain stable for brown trout if the Proposed Action with RFFAs were implemented.

Time series analyses from the Kemp-Breeze Site predict no changes in minimum or average rainbow trout habitat availability greater than 7% as a result of the Proposed Action with RFFAs. Analyses from the above the Kemp-Breeze Ditch Site show large increases in minimum habitat availability (41% to 63%, depending on life stage) in median years, an 18% decrease in minimum juvenile habitat availability in dry years. Average spawning WUA would increase by 15% in median years and 26% in wet years. Analyses from the below Kemp-Breeze Ditch Site indicate a 64% increase in minimum spawning habitat availability and a 29% increase in juvenile habitat availability in median years as a result of the Proposed Action with RFFAs.

No significant changes in sediment cycles or channel morphology are expected as a result of the Proposed Action with RFFAs (refer to Section 4.6.3). Because water temperatures are already of concern in Segment 2 of the Colorado River, the effects of the Proposed Action with RFFAs would be moderate (refer to Section 4.6.2). There have been a small number of exceedances for the MWAT standards at multiple sites in this segment of the Colorado River between 2005 and 2010. Temperature exceedances only occurred on hot days when flows were 125 cfs or less, but the number of days during which flows are 125 cfs or less are expected to increase under the Proposed Action with RFFAs (refer to Section 4.6.2). However, no increase in the frequency of exceedances is expected (refer to Section 4.6.2).

Habitat availability time series analyses indicate that most of the changes would be minimal, generally less than 7%. Most of the changes that were larger indicated substantial increases in habitat availability, especially for rainbow trout. However, rainbow trout account for a small portion of the fish community and the increases in habitat may not have a substantial effect on the total fish community. There are not expected to be changes in channel morphology or water temperatures that would affect aquatic resources. Therefore, the Proposed Action with RFFAs would have negligible cumulative impacts on aquatic resources in Segment 2 of the Colorado River.

Blue River

Four PHABSIM segments were evaluated on the Blue River. Hydrology data from the Dillon Reservoir Outlet (Node 4250) in Segment 1, the Blue River below Boulder Creek (PACSM Node 4500) in Segment 2, the Blue River below Green Mountain Reservoir (PACSM Node 4650) in Segment 3, and Blue River at Mouth (PACSM Node 4800) in Segment 4 were used for evaluation of flow changes and PHABSIM. Habitat data were available for all life stages of brown trout in all four segments of the Blue River; habitat data were available for all life stages of rainbow trout in Segments 2 through 4. The

Proposed Action, Full Use of the Existing System, with RFFAs would increase the frequency and duration of dry years in the Blue River in Segment 1 (refer to Section 4.6.1).

Blue River Segment 1, Dillon Reservoir to Rock Creek

The Proposed Action with RFFAs would result in an annual average of 26% less water in average years and 13% less water in wet years (refer to Appendix Table H-1.63); reductions would be largest from May through August. Reductions in peak flows in average years would be 275 cfs (31%) (refer to Appendix H, Table H-14.4). The Project would not divert more water in dry years, but the other RFFAs would result in 18% less water in dry years. The Proposed Action and other RFFAs would increase the frequency and duration of dry years in the Blue River in Segment 1 (refer to Section 4.6.1).

For brown trout, habitat availability is lowest during spring runoff for all life stages in all year types. The Proposed Action with RFFAs would cause no appreciable changes in minimum habitat availability in median years, but minimum WUA would increase by 13% for adults and by 19% for fry and juveniles in dry years, and minimum spawning WUA would increase by 11% in wet years. Changes in average habitat availability for all life stages would be smaller, less than 7%.

The greater frequency of dry years would increase habitat availability for brown trout by reducing flows during the spring runoff period. For adult, fry, and juvenile brown trout, minimum habitat availability for dry years would be approximately 80% to 100% higher compared to median years and up to 126% compared to wet years. For average habitat availability, dry years result in 17% to 38% higher availability than wet years for the three life stages of brown trout.

Most of the changes in habitat availability would be minimal or slightly beneficial. There would be minor increases in sedimentation in some years with the Proposed Action with RFFAs (refer to Section 4.6.3), which could be unfavorable to both fish and macroinvertebrates. These accumulations would be transported during wet years so that there would be no long-term changes in channel morphology. There are not expected to be any substantial changes to most water quality parameters (refer to Section 4.6.2). However, in years when Dillon Reservoir is full and spills, relatively warm water from the top of the reservoir enters the Blue River and raises the temperature to levels that may result in better growth of trout. With the Proposed Action with RFFAs, Dillon Reservoir spills would decrease by 30 to 40%, which could reduce the time in some years when temperatures are more favorable for trout growth. These reductions in water temperature and the minor increases in sedimentation in some years would result in minor adverse cumulative impacts to aquatic resources in Segment 1 of the Blue River. Density of both fish and macroinvertebrates could be reduced. Segment 1 of the Blue River is on the Monitoring and Evaluation List for low MMI scores. With the Proposed Action with RFFAs, MMI scores would likely continue to be below the threshold for attainment. This segment of the Blue River is not near an ecological tipping point and these changes would not cause it to approach a threshold.

Blue River Segment 2, Rock Creek to Green Mountain Reservoir

The Proposed Action with RFFAs would result in 18% less water in average years and 10% less water in dry and wet years in Segment 2 of the Blue River (PACSM Node 4500). Most of the water would be diverted between May and August in average and dry years, but additional diversions in wet years would occur in October and November.

Time series analyses predicted minimal changes in minimum brown trout habitat availability in median and wet years for all life stages. However, in dry years, the Proposed Action with RFFAs would lead to 32% and 12% increases of brown trout fry and juvenile WUA, respectively. Average habitat availability would also have minimal changes, all less than 10%.

Time series analyses predicted minimal changes in minimum WUA for all life stages of rainbow trout in all year types. Average spawning WUA would increase by 15% in median years, but all other changes would be minor.

Sediment analysis suggests that short-term sediment accumulation could increase, but there would be no long-term changes to sediment cycling or channel morphology. There are not expected to be any substantial changes to most water quality parameters (refer to Section 4.6.2). Because only minimal changes in trout habitat availability are expected, there would be negligible cumulative impacts to aquatic resources in Segment 2 of the Blue River if the Proposed Action with RFFAs are implemented.

Blue River Segment 3, Green Mountain Reservoir to Spring Creek

The Proposed Action with RFFAs would lead to average annual flow reductions of 12% in average years, 5% in dry years, and 8% in wet years (PACSM Node 4650; refer to Appendix Table H-1.59). Flow reductions would be greatest from May through July. Peak flows in average years would be reduced by 35% (refer to Appendix H, Table H-14.4). The seasonal flow pattern in the Blue River downstream of Green Mountain Reservoir is somewhat different than for other large streams in the Project area. Lowest flows occur in April and May, prior to higher flows in June through the summer. Winter flows are relatively high compared to most other streams. This seasonal flow pattern would be maintained with the Proposed Action with RFFAs.

There would be few appreciable changes in brown trout habitat availability with the Proposed Action with RFFAs. Most changes would be 7% or less. The Proposed Action with RFFAs would increase minimum juvenile WUA by 10% in dry years, and minimum spawning WUA would increase by 18% in wet years. Average spawning WUA would increase by 11% in wet years. The Proposed Action with RFFAs would also result in few changes to habitat availability for rainbow trout. There would be an increase rainbow trout minimum spawning WUA by 18% and average spawning WUA by 11% in wet years.

Most of the changes in habitat availability would be minor except for a few increases for spawning and juvenile trout in some years. The changes are likely not sufficient to have any effect on trout populations. There would be negligible cumulative impacts to aquatic resources with the Proposed Action with RFFAs in Segment 3 of the Blue River.

Blue River Segment 4, Spring Creek to Colorado River

The Proposed Action with RFFAs result in average annual flows that would be 11% lower in average years, 5% lower in dry years, and 8% lower in wet years. In average and dry years, flow reductions would occur primarily during spring runoff, but during wet years, largest reductions would occur between October and February, and in May. PHABSIM data were available for brown trout and rainbow trout at two sites in Segment 4, the Blue Valley Ranch Middle Site and Blue Valley Ranch Lower Site.

Time series analyses using brown trout WUA curves from the Middle Site indicate that the Proposed Action with RFFAs would result in small increases in habitat availability. Adult habitat would increase by 10% in dry years, and spawning habitat would increase by 12% in wet years. All other increases would be less than 10%. Average WUA would not increase by more than 6% for any life stage during any year type. Time series analyses using brown trout WUA curves from the Lower Site indicate that there would be no appreciable changes in minimum or average WUA as a result of the Proposed Action with RFFAs.

Time series analyses using rainbow trout WUA curves from the Middle Site indicate that the Proposed Action with RFFAs would result in a small increase in habitat availability. Minimum spawning WUA would increase by 11% in median years, and minimum juvenile WUA would increase by 7% in dry years. No changes in minimum WUA would occur in wet years. All increases in average WUA were 6% or less. Time series analyses using rainbow trout WUA curves from the Lower Site indicated that the Project with RFFAs would produce no appreciable changes in minimum or average rainbow trout habitat availability.

The projected changes in habitat availability for brown and rainbow trout in Segment 4 of the Blue River would be minimal and indicate that there would be negligible cumulative impacts if the Proposed Action and RFFAs are implemented. There are expected to be negligible cumulative changes to populations of macroinvertebrates and fish.

South Boulder Creek

PHABSIM data were available for three Segments of South Boulder Creek. Segments 1 and 2 include the stream between Moffat Tunnel and Gross Reservoir, and Segment 3 is downstream of the reservoir. Hydrology data were available near Rollinsville (PACSM Node 57100) for Segment 1, at the Pinecliffe gage (PACSM Node 57120) for Segment 2, and downstream of Gross Reservoir (PACSM Node 57140) for Segment 3.

Segments 1 and 2, Upstream of Gross Reservoir

In these two segments, the Proposed Action with RFFAs would result in higher mean monthly flows in the runoff period and similar flows to existing conditions in other months. In average years, the average annual flows would be 15% higher at Rollinsville and 12% higher at Pinecliffe and mean monthly flows in June and July would be as much as 25% higher in Segments 1 and 2 with the Proposed Action with RFFAs. At the Pinecliffe gage, average annual peak flows would increase by 128 cfs (18%) (refer to Appendix H, Table H-14.4). In dry years, average annual flows would be 2% higher, but June flows would be up to 13% higher than the Current Conditions average. In wet years, flows would be 23% and 17% higher on an annual basis in Segments 1 and 2, respectively (refer to Appendix Table H-1.65). PHABSIM data were available for adult and spawning life stages of brook trout in Segment 1 and for adult, juvenile, and fry rainbow trout in Segments 1 and 2.

With the higher mean monthly flows during runoff in Segment 1 with the Proposed Action with RFFAs, brook trout minimum adult WUA would decrease by 12% in wet years; all other changes in minimum habitat availability would be 5% or less. Decreases in average habitat availability would be 2% or less for all life stages in all year types.

For rainbow trout in Segment 1, reductions to minimum habitat availability would be 12% for adults and 19% for fry in wet years, but changes in minimum WUA would be 5% or less for all other life stages, regardless of year type. Changes in average WUA were negligible for all life stages in all year types. In Segment 2, changes in minimum and average WUA would be 3% or less for all life stages in all year types.

High flows would occur more often under the Proposed Action with RFFAs. The 5- and 10-year floods would be expected to occur every 4 and 7 years under the Proposed Action with RFFAs. As a result, bank erosion could increase, and further stabilization could become necessary (refer to Section 4.6.3). No changes to water quality would occur that could affect aquatic resources (refer to Section 4.6.2).

There would be mostly minimal changes in trout habitat availability. However, there would be increased bank instability in Segments 1 and 2 of South Boulder Creek, which could alter habitat somewhat. The increases in runoff flows could have an effect on benthic invertebrate populations as well. The Proposed Action with RFFAs would result in minor adverse cumulative impacts and could result in decreased density of macroinvertebrates, or macroinvertebrate community composition could shift towards species that prefer fast-moving water.

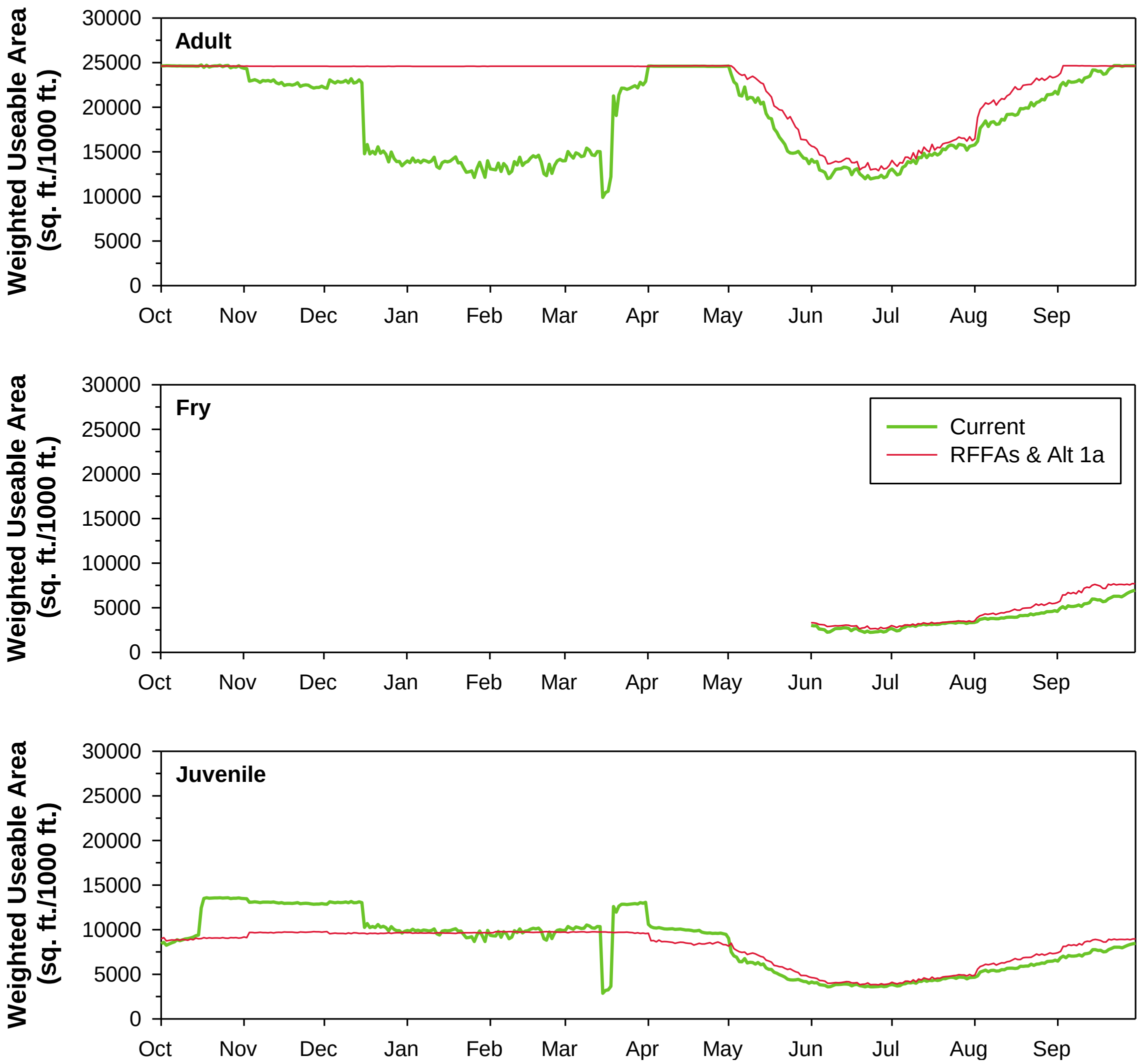
Segment 3, Gross Reservoir to South Boulder Diversion Canal

With the Proposed Action with RFFAs, annual flows would increase by 11% in average years, 21% in dry years, and 17% in wet years (refer to Appendix Table H-1.66). Peak flows would be reduced by 28 cfs (6%) in average years (refer to Appendix H, Table H-14.4). The existing hydrograph has flows that are highest in spring, but they are extremely low in winter. With the Proposed Action with RFFAs, flows in average, dry, and wet years would be substantially different. Flows would increase from November through February compared to Current Conditions (2006); the greatest increases (nearly 700% to 1,100%) would occur in January and February. Flows during runoff would be up to 24% lower.

With existing conditions, the minimum habitat availability for rainbow trout adults (Figure 4.6.11-10), and juveniles occurs in the late winter and during spring runoff. With the Proposed Action with RFFAs, there would be increases in minimum habitat availability up to 126%. For adults, increases would be 30% in median years and 126% in dry years. Fry minimum habitat availability would decrease by 31% in wet years, but it would increase by 16% in median years. Juvenile minimum habitat availability would also increase; predicted increases range from 11% (wet years) to 53% (dry years).

Average habitat availability would also increase for some life stages in all year types. In median years, adult and fry average habitat would increase by 20% and 17%, respectively. Adult WUA would increase by 24% in dry years and by 16% in wet years. Changes for other life stages in dry and wet years would be 8% or less.

Figure 4.6.11-10
WUA for Three Life Stages of Rainbow Trout in Segment 3 of South Boulder Creek for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



Winter flows would increase under the Proposed Action with RFFAs, but highest runoff flows would be reduced by up to 12%. The 5-year flood would only occur every 12 years, and the 10-year flood would not be expected to occur under the Proposed Action with RFFAs. These changes may decrease bank instability in Segment 3 of South Boulder Creek and reduce the need for further bank stabilization efforts (refer to Section 4.6.3).

No changes to water quality would occur that could affect aquatic resources except for water temperature (refer to Section 4.6.2). Water temperatures throughout the year are expected to be lower with the Proposed Action with RFFAs compared to Current Conditions (2006) with the expansion of Gross Reservoir. Temperatures during the growing season for trout would be several degrees cooler and would be less favorable for growth. Cooler temperatures are expected throughout this segment downstream to the

South Boulder Creek Diversion as there is little warming of the water in this segment (refer to Section 4.6.2).

The increases in winter flows would result in large increases in rainbow trout habitat availability and the small decreases in spring runoff flows would decrease conditions that may be stressful to early life stages of this species. The higher winter flows would likely alleviate winter low flow habitat limitations. However, the cooler temperatures throughout the year would limit trout growth and survival and likely dampen the beneficial effects of greater habitat availability. Higher winter flows and reduced peak flows would also provide more uniform flow conditions for benthic invertebrates. With less dramatic drying of the stream in winter months, Segment 3 of South Boulder Creek may support a higher density of macroinvertebrates or a more species-rich community including more rheophilic species. Community metrics such as diversity and the number of EPT species may increase. The increases in habitat availability for rainbow trout and macroinvertebrates indicate that the Proposed Action with RFFAs would have minor beneficial cumulative impacts on aquatic resources in Segment 3 of South Boulder Creek.

North Fork South Platte River

There are two segments on the North Fork South Platte River with PHABSIMs. In Segment 1, hydrology data from the North Fork Platte below Geneva Creek gage (PACSM Node 50700) were used for habitat simulation. In Segment 2, hydrology data from the North Fork South Platte above Pine (PACSM Node 50750) were used.

Segment 1, Roberts Tunnel to Buffalo Creek

The Proposed Action with RFFAs would result in many differences in flow compared to existing conditions. The average annual flow would increase by 26% in average years, 24% in dry years, and 17% in wet years, and the timing of the flows would change considerably (refer to Appendix Table H-1.68). Peak flows would increase by 31% (refer to Appendix H, Table H-14.4). Mean monthly flows would decrease in winter by as much as 26% (January and February of wet years), and they would increase during spring runoff by as much as 79% (September of wet years). This would result in increased seasonal flow fluctuation and a prolonged runoff period, compared to Current Conditions.

Habitat simulation data were available for all four life stages of brown trout in Segment 1. With Current Conditions, minimum habitat availability occurs during runoff in June for adult, fry, and juvenile brown trout. Reductions in habitat availability are would occur for all life stages in median and dry years: minimum WUA reductions would range from 23% to 28% in median years and from 20% to 28% in dry years, depending upon life stage. In wet years, only minimum spawning WUA was reduced (25% loss). Average habitat availability would be less affected, but reductions were consistently predicted for early life stages, fry and juveniles. In median years, fry and juvenile WUA would be reduced by 20% and 10%, respectively. Average fry WUA would also be reduced in other year types; losses would be 15% in dry years and 17% in wet years. Reductions in adult and spawning habitat would be 9% or less in all year types.

Although water quality may change due to changes in flows from the Roberts Tunnel, these changes will generally not lead to exceedances of Aquatic Life water quality standards. There could be increases in copper concentrations, which already sometimes exceed standards (refer to Section 4.6.2). Increased flows are expected to increase bank instability, and further bank armoring may be required to stabilize affected areas (refer to Section 4.6.3).

The changes in flow with the Proposed Action with RFFAs would tend to be unfavorable for brown trout, and the Proposed Action with RFFAs would have moderate adverse cumulative effects on resident populations, particularly because early life stages would be affected in all year types. The adverse effects to brown trout could be exacerbated by localized bank instability. These effects could lead to decreases in trout density in Segment 1 of the North Fork South Platte River. The increases in flows during runoff and increased concentrations of copper may result in lower density or fewer species of macroinvertebrates although there may be more rheophilic species. Overall, there would be moderate adverse cumulative impacts in Segment 1.

Segment 2, Buffalo Creek to South Plate River

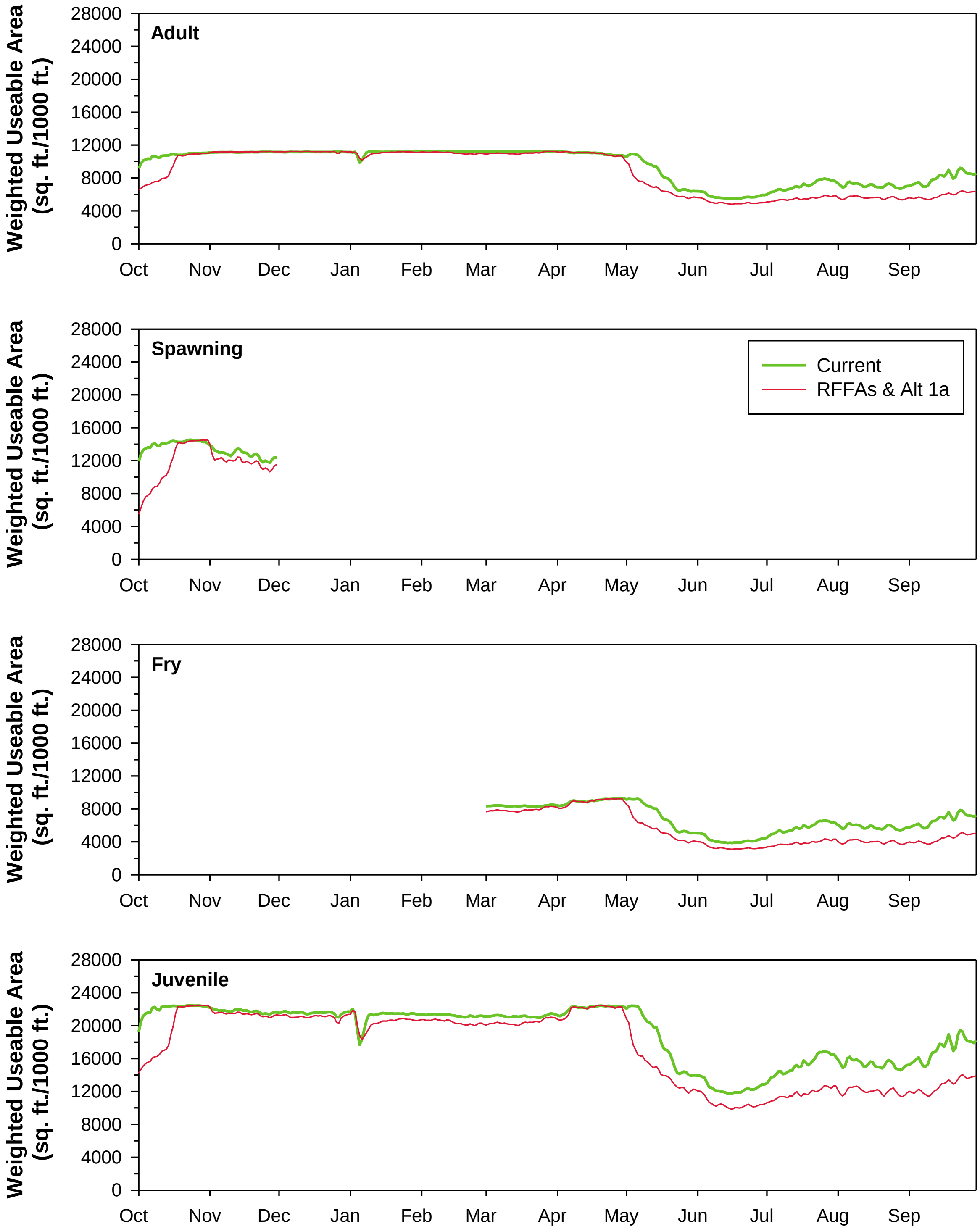
The effects of the Proposed Action with RFFAs on flows in Segment 2 of the North Fork South Platte River would be similar to those in Segment 1. The average annual flow would increase by 22% in average and dry years and by 11% in wet years, and the timing of the flows would change considerably. Mean monthly flows would decrease in winter by as much as 22% (February of wet years), and they would increase during summer by as much as 60% (September of wet years). This would result in increased seasonal flow fluctuation and a prolonged runoff period compared to existing conditions.

In Segment 2, lowest habitat availability occurs during high flows. Minimum habitat availability would decrease for all four life stages of brown trout (Figure 4.6.11-11). Predicted minimum habitat availability decreases from 12% for adults to 53% for spawning in median years and from 13% for adults to 68% for spawning in dry years. In wet years, only spawning habitat would be appreciably reduced, but losses would be 60%. Average habitat availability would also decrease for all four life stages: in median years, predicted reductions range from 8% for adults to 20% for fry, in dry years, predicted reductions range from 7% for adults to 18% for fry, and in wet years, reductions range from 7% for adults to 15% for fry.

Although water quality in Segment 2 of the North Fork South Platte River may be affected by changes in flows from Roberts Tunnel, no exceedances of Aquatic Life water quality standards are expected. The only potential exception is copper (refer to Section 4.6.2). Increased flows are expected to increase bank instability, and further bank armoring may be required to stabilize affected areas, but Segment 2 of the North Fork South Platte River would be less affected than Segment 1 (refer to Section 4.6.3).

Consistent losses in habitat for all life stages across all year types suggests that the Proposed Action with RFFAs would have moderate adverse cumulative effects on brown trout populations in Segment 2 of the North Fork South Platte River. The adverse effects to brown trout could be exacerbated by localized bank instability and could lead to decreases in trout density in Segment 1 of the North Fork South Platte River. The increase in flows and the possible increase in bioavailable copper would likely decrease invertebrate densities and species richness.

Figure 4.6.11-11
WUA for Four Life Stages of Brown Trout in Segment 2 of the North Fork South Platte River for a Median Year Under Current Conditions (2006) and the Proposed Action with RFFAs (2032)



South Platte River

Antero Reservoir to North Fork South Platte River

Cumulative flow changes to the South Platte River upstream of the North Fork would be minor. There would be no impact to aquatic resources to the river or the reservoirs in this section.

Segment 4, North Fork South Platte River to Strontia Springs Reservoir

The short segment of the South Platte River between the North Fork and Strontia Springs Reservoir would have increased flows with the Proposed Action with RFFAs. The changes are not modeled but may be near 10% based on the flow changes in the North Fork. There is no fish habitat simulation available for this short segment. The small changes in hydrology likely would have negligible cumulative impacts to aquatic resources in this segment.

Segment 5, Strontia Springs Reservoir to Chatfield Reservoir

Hydrology at the Waterton gage (PACSM Node 51200) indicates a decrease in average annual flow of 13% in average years with most of the decrease in the runoff months (refer to Appendix Table H-1.72). In dry and wet years, the changes in annual flow would be 6% or less but changes in some of the individual months would be from 10% to 20%. Peak flow in an average year would be reduced by 42 cfs (6%) (refer to Appendix H, Table H-14.4).

PHABSIMs are available for life stages of brown and rainbow trout for Segment 5 of the South Plate River. Changes in habitat availability for brown trout would be 5% or less except for a 30% increase for minimum habitat availability for adults in wet years. For rainbow trout, most of the changes would be 9% or less except for reductions in minimum or average spawning habitat availability of 15% to 88% and an increase in juvenile habitat of 27% in dry years.

There would be no changes in water quality or channel morphology that would affect aquatic resources in this segment (refer to Sections 4.6.2 and 4.6.3). Most of the changes in habitat would be minimal. There would be negligible cumulative impacts to aquatic resources in Segment 5 of the South Platte River under the Proposed Action with RFFAs.

Segment 6, Chatfield Reservoir to Bear Creek

One PHABSIM habitat suitability relationship for Segment 6 was simulated for the section of the South Platte River downstream of Chatfield Reservoir using hydrology data from the South Platte River below Chatfield (PACSM Node 51290). Habitat simulation data were available for four life stages of rainbow trout. Rainbow trout populations are maintained by stocking in this segment and changes in habitat availability, especially for the spawning life stage, may not affect fish populations as directly as in sections of the Project area with self-sustaining populations of trout. Therefore, the habitat analysis for Segment 1 of the South Platte River incorporated a qualitative evaluation intended to apply to the broad range of species that are present in this segment.

In average years, mean annual flows would be 12% less, in dry years, they would be 7% less, and in wet years, they would be 6% less (refer to Appendix Table H-1.73). In average years, reductions would be greatest in July and August, but flows would increase from

November through January. In dry years, flow decreases would be greatest in July and August, but flows would increase by as much as 77% in winter months. In wet years, flow decreases would be greatest in February (15%), but flows would increase in December, January, and March.

Minimum habitat availability under Current Conditions occurs during the low flow winter period for adult rainbow trout and likely for most other fish species in this segment. Flows in this segment of the river are commonly very low throughout the winter of all three year types. Under Current Conditions, minimum habitat availability for most or all fish species and invertebrates probably occurs during the winter.

In dry years, adult and juvenile minimum habitat availability would increase by 192%, but spawning and fry habitat would decrease by 19% and 9%, respectively. In wet years, adult and spawning habitat availability would decrease by 37% and 72%, respectively. In median years, changes would be 1% or less for fry, juveniles, and adults. Average annual habitat availability for rainbow trout would be less affected by the Proposed Action with RFFAs. The changes in average habitat availability mostly would be 7% or less. Fry WUA would increase by 13% in median years, and spawning WUA would increase by 34% in dry years. Because the trout populations in this area are maintained by stocking juvenile and adult fish, changes in spawning or fry WUA would have negligible cumulative effects on the limited trout population.

There would be no water quality changes that would affect fish and invertebrates in this segment of the South Platte River (refer to Section 4.6.2). There likely would not be changes to channel morphology in this segment of the South Platte River with the Proposed Action with RFFAs due to the channelization along almost all of its length.

The increases in minimum habitat availability in this segment are largely due to increased flow in winter of dry years. This would result minor beneficial cumulative impacts in Segment 6. Large historic changes to native flows and stream morphologies in plains streams such as the South Platte River restrict the current fish assemblage mainly to tolerant species. Many of the remaining native Great Plains fishes in the Project area can tolerate flashy flows and poor water quality (Cross and Moss 1987; Fausch and Bestgen 1997). These species also tend to have generalized habitat requirements and prolonged spawning seasons (Fausch and Bestgen 1997). These species weather abrupt changes in stream flow (i.e., floods, intermittency) and/or physicochemical conditions through refuging behaviors, rapid reproduction, and recolonization of extirpated areas (Dodds et al. 2004). Therefore, the Proposed Action with RFFAs should have negligible cumulative effects on the South Platte River fish assemblage.

4.6.11.2 Alternative 1c with Reasonably Foreseeable Future Actions

Gross Reservoir

The enlargement of Gross Reservoir would provide more habitat for fish and invertebrates. The final surface area of the reservoir under Alternative 1c would be approximately 650 acres, 53% larger than the existing reservoir. This would be a moderate beneficial cumulative impact to the reservoir fishery for Alternative 1c compared to Current

Conditions. The beneficial impact would be slightly less than for the Proposed Action, which would result in Gross Reservoir enlarged to 842 acres.

Construction activities during enlargement would not substantially affect the normal operation of the reservoir. The fish and invertebrate communities in the reservoir would continue to function as normal. RFFAs are not likely to have any cumulative effects on aquatic biological resources at Gross Reservoir, beyond those associated with the Moffat Project alternatives, because no major actions that would impact fish or invertebrates and their habitat are planned in this area.

Leyden Gulch Reservoir Site

With Alternative 1c, Leyden Gulch Reservoir would be created. This would represent a gain of approximately 331 acres of reservoir habitat available for fish, invertebrates, and other aquatic organisms. This would represent a minor beneficial impact under Alternative 1c compared to Current Conditions. However, the public would not have access to the reservoir. This indicates that the reservoir fishery would not be managed and would probably include only a few fish species, with no recreational fishery. The creation of the reservoir would inundate portions of Leyden Gulch. Past actions that have affected aquatic habitats in the Leyden Gulch Reservoir study area include construction of the existing Ralston Reservoir and other reservoirs, installation of culverts at road and railroad crossings, and changes in drainage patterns related to roads, railroads and other developments. This stream is ephemeral in this section and does not support aquatic life. A small spring pool on a south branch of Leyden Gulch would also be inundated under the new reservoir. This pool supports a limited community of aquatic organisms. The inundation of this pool would represent a minor adverse cumulative impact under Alternative 1c.

River Segments

Cumulative impacts to all river segments with Alternative 1c would be similar to those described for the Proposed Action with RFFAs.

4.6.11.3 Alternative 8a with Reasonably Foreseeable Future Actions

Gross Reservoir

The enlargement of Gross Reservoir would provide more habitat for fish and invertebrates. The final surface area of the reservoir would be approximately 712 acres, 70% larger than the existing reservoir. This would be a moderate beneficial impact to the reservoir fishery for Alternative 8a compared to Current Conditions. The beneficial impact would be slightly less than for the Proposed Action, which would result in Gross Reservoir enlarged to 842 acres.

Construction activities during enlargement would not substantially affect the normal operation of the reservoir. The fish and invertebrate communities in the reservoir would continue to function as normal. RFFAs are not likely to have any cumulative effects on aquatic biological resources at Gross Reservoir, beyond those associated with the Moffat Project alternatives, because no major actions that would impact fish or invertebrates and their habitat are planned in this area.

South Platte River Facilities

Alternative 8a would include approximately 5,000 acre-feet (AF) of storage capacity in reclaimed gravel pits adjacent to the South Platte River. The pits would typically fill with reusable effluent from November through April, when unused reusable effluent is available. Filling and operation of the gravel pit reservoirs would provide aquatic resources with approximately 5,000 AF of open water habitat. This habitat would likely be colonized by aquatic invertebrates and fish over time. This would represent a moderate beneficial impact of Alternative 8a.

The diversion structure for filling the gravel pit reservoirs would include a buried pipe connected from the South Platte River to a gravel pit. Direct minor adverse impacts on aquatic biological resources from construction of the diversion would include temporary disturbance in the South Platte River for the duration of construction. Cumulative effects are unlikely for aquatic resources at the South Platte River Facilities because Project-related activities would have only temporary impacts.

Conduit O

Conduit O would cross several streams, including the South Platte River, containing communities of warmwater fish and invertebrates. Crossing of the streams would be open cut per Denver Water's standard practice. Each crossing would be completed in approximately 20 working days, depending on weather and other conditions. Therefore, direct minor adverse impacts on aquatic resources from construction would include temporary disturbance for the duration of construction. Cumulative effects are unlikely for aquatic resources for Conduit O because Project-related activities would have only temporary impacts.

River Segments

Cumulative impacts to all river segments with Alternative 8a would be similar to those described for the Proposed Action with RFFAs.

4.6.11.4 Alternative 10a with Reasonably Foreseeable Future Actions

Gross Reservoir

Impacts to fish and invertebrate communities would be the same as described under Alternative 8a.

Denver Basin Aquifer Facilities

The proposed distribution pipelines would cross four streams, including the South Platte River, containing communities of warmwater fish and invertebrates. The types of temporary impacts would be similar to those described for Conduit O. Cumulative effects are unlikely for aquatic resources at the crossings because Project-related activities would have only temporary impacts.

Conduit M

The alignment for Conduit M is the same for Conduit O between the Moffat Collection System delivery point and the intersection of 80th Avenue and Pierce Street. Streams crossed include Little Dry Creek, Clear Creek, and the South Platte River. The temporary, direct minor adverse impacts of construction activities on Conduit M for Alternative 10a on aquatic biological resources in these streams would be the same as described for Conduit O under Alternative 8a. Cumulative effects are unlikely for aquatic resources for Conduit M, because Project-related activities would have only temporary impacts.

River Segments

Cumulative impacts to all river segments with Alternative 10a would be similar to those described for the Proposed Action with RFFAs.

4.6.11.5 Alternative 13a with Reasonably Foreseeable Future Actions

Gross Reservoir

The enlargement of Gross Reservoir would provide more habitat for fish and invertebrates. The final size of the reservoir would be approximately 754 acres. This would be a moderate beneficial impact to the reservoir fishery for Alternative 13a compared to Current Conditions. The beneficial impact would be slightly less than for the Proposed Action, which would result in Gross Reservoir enlarged to approximately 842 acres.

Construction activities during enlargement would not substantially affect the normal operation of the reservoir. The fish and invertebrate communities in the reservoir would continue to function as normal. RFFAs are not likely to have any cumulative effects on aquatic biological resources at Gross Reservoir, beyond those associated with the Moffat Project alternatives, because no major actions that would impact fish or invertebrates and their habitat are planned in this area.

South Platte River Facilities

The cumulative beneficial impacts from gravel pit storage would be similar to those described under Alternative 8a, except that only 3,625 AF of open water habitat would be created under Alternative 13a.

Additionally, the gravel pit pipeline would extend 5 miles to the northern Challenger Pit and would cross the South Platte River at Bridge Street. There would be temporary direct minor adverse impacts during construction at the crossing. Cumulative effects are unlikely for aquatic resources at the South Platte River crossing because Project-related activities would have only temporary impacts.

Conduit O

Impacts from construction of Conduit O would be the same as described for Alternative 8a.

River Segments

Cumulative impacts to all river segments with Alternative 13a would be similar to those described for the Proposed Action with RFFAs.

4.6.11.6 No Action Alternative with Reasonably Foreseeable Future Actions

Depletion of Strategic Water Reserve Strategy

Under the No Action Alternative, Denver Water would continue to operate its existing system. The hydrology for the No Action Alternative would be much different compared to all other alternatives. Diversions from the Fraser and Williams Fork tributaries would be much less than for the action alternatives and, therefore, less water would be delivered to South Boulder Creek than for the other alternatives and Gross Reservoir would not be enlarged. The differences between the No Action Alternative and the other alternatives would not result in substantial differences in channel morphology impacts except in South Boulder Creek where the lower flows would have an insignificant impact compared to the increased erosion with RFFAs and the other alternatives (refer to EIS Section 4.6.3). For water quality, the No Action Alternative would have similar impacts to the other alternatives. The cumulative impacts of changes in hydrology for the No Action Alternative on fish and invertebrates are discussed below. The cumulative impacts of the No Action Alternative with RFFAs would have the same tipping point consequences as described for the Proposed Action with RFFAs. As explained for the Proposed Action with RFFAs, in almost all cases, there would be no changes that would be sufficient to cause a stream to cross an ecological tipping point.

Gross Reservoir

Gross Reservoir would not be enlarged with the No Action Alternative. Reservoir volume would generally be lower, by up to 11% in some months. The reservoir would also be drawn down to the minimum pool approximately 50% more often. Water quality impacts may include a slight increase in phosphorus levels leading to slightly higher productivity than for the other alternatives which could be beneficial to the fishery. However, the lower volume of the reservoir indicates there would be a minor adverse impact to the fish and invertebrate community of Gross Reservoir with the No Action Alternative compared to Current Conditions.

Fraser River

The No Action Alternative with RFFAs would divert more water from the Fraser River Basin tributaries in average and wet years compared to existing conditions. In general, flow depletions with the No Action Alternative would be just over half that with the other alternatives. The flow reductions in the Fraser River would range from 5% at Granby (PACSM Node 2900) up to 23% downstream of Vasquez Creek (PACSM Node 2600) compared to existing conditions.

The differences in flow between the No Action Alternative and Current Conditions would result in some differences in habitat availability. For brook, trout in Segment 1 of the Fraser River, the differences in minimum and average habitat availability would be less than 8% with the No Action Alternative and there would be negligible cumulative impacts compared to the minor adverse impact with the Proposed Action with RFFAs. In Segment 2, minimum brook trout WUA for adults and spawning would be reduced by 15 to 22%, and average brook trout WUA would be decreased by up to 17% with the No Action Alternative. This indicates there would be moderate adverse cumulative impacts on aquatic resources, similar to the impact with the Proposed Action and RFFAs. The reduced runoff flows in Segment 3 of the river would result in increases in minimum habitat availability of up to 10% to 25% in median years for adult and juvenile rainbow and brown trout. The changes in average habitat availability would be 5% or less. The No Action Alternative would have minor beneficial cumulative impacts in Segment 3; an impact somewhat less than the moderate beneficial impacts under the Proposed Action with RFFAs. In Segments 4 and 5 of the Fraser River, the changes in habitat availability for the life stages of brown and rainbow trout would all be 7% or less except for a 10% reduction in rainbow trout spawning habitat in dry years in Segment 4. These minimal changes in habitat availability would have negligible cumulative impacts on aquatic resources for the No Action Alternative, the same as for the Proposed Action with RFFAs. However, under certain conditions, bypass flows may not be met below diversions in the Fraser River Basin. This could further reduce flows compared to Current Conditions of low habitat availability for fish and invertebrates. If bypass flows are not met, there would be additional adverse cumulative impacts to aquatic resources and possibly water temperatures in the upper Fraser River.

Fraser River Tributaries

Cumulative reductions in flow in Fraser River tributaries between the No Action Alternative and Current Conditions would be one third to one half as much as would be diverted with the Proposed Action with RFFAs. Compared to existing conditions, the No Action Alternative and other RFFAs would divert between 2% and 28% more water in average years and between 3% and 34% in wet years. In dry years, the additional diversions would be less than 10% compared to existing conditions and there would be increases in flow in a few streams. The differences would not affect the low winter flows that are now present in many of these streams.

In many of the Fraser River tributaries, the increased diversions with the No Action Alternative are less than with the Proposed Action compared to Current Conditions (2006), but would still be high enough to result in minor cumulative impacts, similar to the Proposed Action with RFFAs. This includes the St. Louis Creek tributaries, King Creek, Main Elk Creek and tributaries, Little Vasquez Creek, Cooper Creek, Jim Creek, Middle Fork and South Fork Ranch Creek, Wolverine Creek, Cub Creek, and Buck Creek. For these streams, the minor impact with the No Action Alternative would be similar to the minor cumulative impacts described for the Proposed Action with RFFAs.

In St. Louis Creek, the No Action Alternative would have reductions in flow due to additional diversions of 7% on an average annual basis compared to Current Conditions but monthly flow reductions could be as high as 28% during the runoff period. However, habitat availability for brook trout would change by 2% or less for median, dry and wet years. As a result, habitat availability changes under the No Action Alternative and other RFFAs would be similar to the Proposed Action. The No Action Alternative would have negligible cumulative impacts on fish and invertebrates in St. Louis Creek.

In Vasquez Creek, the additional diversions with the No Action Alternative would be 35% on average compared to Current Conditions, about two thirds of the additional diversion with the Proposed Action with RFFAs. Changes in habitat availability for brook trout would be very similar for both the No Action Alternative and the Proposed Action with RFFAs due to lower winter flows. The No Action Alternative with RFFAs would have moderate adverse cumulative impacts similar to the cumulative impacts for the Proposed Action with RFFAs.

In North Fork Ranch, Main Ranch, and Dribble creeks, the additional diversions with the No Action Alternative would be 8% or less compared to Current Conditions, less than would be diverted for the Proposed Action with RFFAs. The No Action Alternative with RFFAs would have negligible cumulative impacts while the Proposed Action with RFFAs would have minor adverse cumulative impacts.

For the streams in the Englewood Ranch Gravity System, the additional diversions would be similar with the No Action Alternative and the Proposed Action with RFFAs. For both alternatives, there would be negligible cumulative impacts to aquatic resources.

Under certain conditions, bypass flows may not be met below diversions in the Fraser River Basin. This could further reduce flows compared to existing conditions of low habitat availability for fish and invertebrates. If bypass flows are not met in some tributaries, there would be additional adverse impact to aquatic resources in the tributaries.

Williams Fork River

Changes in Williams Fork River flows with the No Action Alternative with RFFAs would be minimal, usually 3% or less in all months, and about half that of the Proposed Action. Changes in the minimum habitat availability for brook trout would be less than 1% for both life stages in all year types. The No Action Alternative would have negligible cumulative impacts on the fish and invertebrate communities in the Williams Fork River, similar to the Proposed Action with RFFAs.

Williams Fork Tributaries

The No Action Alternative with RFFAs would divert more water from the Williams Fork tributaries in some months in average and wet years. However, the proposed flow changes would be approximately half that for the action alternatives in average and wet years. In dry years additional flow reductions would be similar to the action alternatives. However, the No Action Alternative would divert approximately 16% more water on an average annual basis and much more in the runoff months. The No Action Alternative would have minor adverse cumulative impacts on fish and invertebrates in the tributaries similar to the Proposed Action with RFFAs.

Colorado River

Reductions in flow with the No Action Alternative with RFFAs in the two segments of the Colorado River would be only slightly less than the reductions with the Proposed Action. Fish habitat availability for the two alternatives would be very similar. The No Action Alternative with RFFAs would have negligible cumulative impacts similar to impacts on fish and invertebrates in the Colorado River as the Proposed Action with RFFAs.

Blue River

Monthly reductions in Blue River flows under the No Action Alternative with RFFAs would be slightly higher than for the Proposed Action with RFFAs. The changes in flow would not result in changes in habitat availability for brown and rainbow trout compared to the Proposed Action with RFFAs. Therefore, the No Action Alternative would have similar cumulative impacts to the Proposed Action with RFFAs in the Blue River.

South Boulder Creek

In all three segments of South Boulder Creek, the flows with the No Action Alternative would be similar to Current Conditions. The increases in average annual flows would be 6% or less in Segments 1 and 2 upstream of Gross Reservoir and only 4% downstream of Gross Reservoir in Segment 3. Monthly flows would vary by a greater magnitude; increases would be as high as 59% in some winter months in Segment 3. The differences in flow would result in differences in channel morphology in South Boulder Creek. The changes in bank erosion for the Proposed Action with RFFAs would not occur with the No Action Alternative.

Changes in trout habitat availability from existing conditions would be usually less than 5% for all life stages of trout in Segments 1, 2, and 3 of South Boulder Creek. The releases of water from Gross Reservoir would have similar temperatures to Current Conditions (2006). The No Action Alternative would have negligible cumulative impacts on the fish and invertebrate communities in Segments 1, 2, and 3 of South Boulder Creek. This would be different than the minor adverse cumulative impacts in Segments 1 and 2 and the moderate beneficial cumulative impact in Segment 3 for the Proposed Action with RFFAs.

North Fork South Platte River

With the No Action Alternative, the increases in flow in the North Fork South Platte would be only slightly larger than for the Proposed Action with RFFAs. This would have only a minimal effect on habitat availability, channel morphology, and water quality. The No Action Alternative with RFFAs would have moderate adverse cumulative impacts to aquatic resources similar to the cumulative impacts for the Proposed Action with RFFAs.

South Platte River

Similar to the North Fork, with the No Action Alternative, the increases in flow in the South Platte River would be only slightly larger than for the Proposed Action with RFFAs. This would have only a minimal effect on habitat availability, channel morphology, and water quality. The No Action Alternative with RFFAs would have cumulative impacts to aquatic resources similar to the cumulative impacts for the Proposed Action with RFFAs.

Combination Strategy

There would be no significant differences to aquatic biological resources under the No Action Alternative Combination Strategy. In dry years, flow changes would be similar under either No Action Strategy. Refer to EIS Section 4.1 for a discussion regarding the flow changes under the Combination Strategy for surface water resources.

Under the Combination Strategy, imposing restrictions would generally have the impact of reserving more water in storage; therefore, storage contents in Denver Water's reservoirs could be higher in dry years. Whether storage contents are higher depends on several factors. The amount and location of water reserved in storage would vary depending on the severity and duration of restrictions imposed, on storage conditions in Denver Water's North and South systems and on hydrologic conditions. Since storage contents could be higher with restrictions, Denver Water's diversions into storage after a drought could be less and stream flows could increase for a short duration after Denver Water's reservoirs refill. However, this would not occur if a reservoir is drained even with restrictions in place. Conversely, with greater restrictions, during a drought stream flows would be less in some streams as Denver Water would decrease its releases from storage and divert additional water if bypass flows are reduced. Decreases in stream flow because less water would be released from storage to meet demand applies to South Boulder Creek below Gross Reservoir, the North Fork South Platte River, and South Platte River. Decreases in stream flow because bypass flows are reduced applies to several locations in the Fraser River Basin, the Blue River below Dillon Reservoir, and along the South Platte River below Eleven Mile Canyon Reservoir and Cheesman Reservoir, and at the Old Last Chance Ditch Diversion. Changes in stream flow between the two No Action Alternative strategies are not expected to be significant. If bypass flows are not met, there would be minor adverse cumulative impacts to aquatic resources in the affected streams.

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4.6.12 Transportation

The affected environment for transportation is described for Current Conditions (2006) in Section 3.12. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential effects to transportation are evaluated against Current Conditions (2006).

Incremental cumulative effects on transportation associated with the Moffat Project alternatives would generally be minor and temporary. The maximum construction duration would be approximately 4 years and traffic impacts would end when construction is completed. The traffic impacts from Moffat Project facility maintenance operations would be ongoing and relatively minor. Analyses of Moffat Project effects in Section 5.12 indicate that these activities would produce negligible effects in relation to the current and projected regional traffic volumes and patterns. Many facilities would operate intermittently during dry years or emergencies and no additional Board of Water Commissioners (Denver Water) staff would be required for maintenance.

Population growth and land development in the Front Range will likely increase traffic in the Project area. Given that additional traffic is likely to be generated from local growth irrespective of the relative traffic impacts associated with construction and maintenance operations of proposed Moffat Project facilities, cumulative impacts would be negligible. As described in Section 4.3, Denver Regional Council of Government’s 2030 Metro Vision Regional Transportation Plan identifies the need for large-scale transportation improvements in order to accommodate population growth, development, and subsequent increases in traffic.

4.6.12.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Expansion of the dam, reservoir, and related facilities under the Proposed Action is expected to be completed within a 4.1-year (49 months) period. Based on the relationship of workforce, equipment, and supply delivery trips, the highest number of trips for dam and reservoir construction is about 214 peak-hour vehicle trips. This number of trips has negligible impact on the operating conditions (i.e., level of service) of the freeways, major arterials, and minor arterials that serve the Gross Reservoir site. Temporary moderate impacts to traffic operations during construction would be passenger vehicle delays due to queuing behind slower-moving haul and supply vehicles on two-lane roads, and queuing at intersections where large vehicle turn movements are more difficult. Traffic impacts associated with travel delays would end when construction is completed. Additionally, no change from Current Conditions (2006) in maintenance and operation trips for the dam and reservoir are anticipated once construction activities are complete.

The additional shoreline created under the Proposed Action may increase recreational traffic on certain roads leading to the reservoir, creating negligible cumulative effects in relation to the current and projected regional traffic volumes and patterns in the Project area. Overall, minimal cumulative effects to transportation are anticipated within the Gross Reservoir study area.

4.6.12.2 Alternative 1c with Reasonably Foreseeable Future Actions

The total environmental effects to transportation at Gross Reservoir under Alternative 1c are generally the same as those described for the Proposed Action with RFFAs, except with a shorter construction period (3.1 years or 37 months) and fewer vehicle trips per day.

The proposed Leyden Gulch Reservoir and related facilities are expected to be completed within a 3.5-year (42 months) period. Since borrow material for the dam would be quarried on-site, construction-related traffic would primarily consist of commuting workers. Based on the relationship of workforce and equipment, the total highest number of trips for dam and reservoir construction is about 484 peak-hour vehicle trips. This number of trips has no significant impact on the operating conditions (i.e., level of service) of the freeways, major arterials, and minor arterials that serve the Leyden Gulch Reservoir site. The indirect temporary impacts to traffic operations would be relatively minor passenger vehicle delays due to queuing behind slower-moving construction equipment vehicles. The frequency and time duration of these traffic delays, and the numbers of people affected by them, pose no significant cumulative impacts.

The current staff at the Ralston Reservoir Facility would operate and maintain the new Leyden Gulch Reservoir using existing roads or Denver Water access roads between the two reservoirs. Thus, none to negligible impacts cumulative impacts to transportation resulting from operations and maintenance activities at the Leyden Gulch Reservoir site are anticipated.

No recreational facilities or public access would be provided at the proposed Leyden Gulch Reservoir.

Transportation improvements and industrial/office redevelopment may occur at the intersection of State Highway (SH) 72 and SH 93, which may increase traffic near the Leyden Gulch Reservoir site. These RFFAs would occur irrespective of the development of Leyden Gulch Reservoir. Additionally, once construction is completed, only operations vehicles would be traveling to the reservoir site, creating none to negligible cumulative effects.

4.6.12.3 Alternative 8a with Reasonably Foreseeable Future Actions

The total environmental effects to transportation at Gross Reservoir under Alternative 8a are generally the same as those described for the Proposed Action with RFFAs, except with a shorter construction period (3.2 years or 38 months) and fewer vehicle trips per day.

The proposed South Platte River Facilities including the diversion structure, the Advanced Water Treatment Plant (AWTP), and dechlorination facility would be expected to be completed within 2.5 years (30 months). Construction-related traffic would primarily consist of workers commuting to and from the construction site. Based on the relationship of workforce and equipment, the total highest number of trips for construction is about 262 peak-hour vehicle trips. This number of trips would have none to negligible cumulative impacts on the operating conditions (i.e., level of service) of the freeways, major arterials, and minor arterials that serve the Project area. The roadways that would be most affected during construction of the South Platte River Facilities are U.S. Highway (US) 85 and local roads in the Brighton area.

Conduit O would take approximately 2.5 years (30 months) to construct. Based on the relationship of workforce and equipment, the total highest number of trips for construction of Conduit O is about 52 peak-hour vehicle trips. This number of trips would have none to negligible cumulative impacts on the operating conditions (i.e., level of service) of the freeways, major arterials, and minor arterials that serve the Project area. Major transportation corridors crossed would be three railroad grades, two highways (Interstate 25 [I-25] and US 36), and seven major arterials (Sheridan, Wadsworth, Federal, Kipling, 104th, 120th, and Washington). Major conduit construction would occur at production rates ranging from about 500 to 1,200 feet per day depending on localized conditions, so that a particular stretch of roadway would typically be impacted by pipeline construction for less than 1 week. Crossings of railroads and major roads would be bored and jacked per Denver Water's standard practices. Each crossing would be completed within approximately 20 working days depending on weather and flow conditions. Pipeline construction would result in temporary moderate cumulative impacts to traffic.

The South Platte River Facilities would operate only during dry years or emergencies. The staff needed to operate these facilities would come from existing Denver Water Facilities when needed. Thus, no cumulative impacts to transportation would result from operations and maintenance activities at the South Platte River Facilities.

No recreational facilities or public access would be provided at the South Platte River Facilities.

The temporary cumulative impacts to traffic operations at the South Platte River Facilities would primarily be passenger vehicle delays on local roads due to queuing behind slower-moving construction equipment vehicles, and higher than average volumes of commuter traffic during peak construction, especially during construction of Conduit O. Overall, cumulative effects to transportation at the South Platte River Facilities are expected to be negligible, particularly in comparison with traffic associated with existing and projected development in Adams County and other urbanized portions of the Project area.

4.6.12.4 Alternative 10a with Reasonably Foreseeable Future Actions

The total environmental effects to transportation at Gross Reservoir under Alternative 10a are the same as those described for Alternative 8a.

The proposed Denver Basin Aquifer Facilities are expected to be completed within a 2.5 year period (30 months). Based on the relationship of workforce and equipment, the total highest number of trips for Alternative 10a construction is about 444 peak-hour vehicle trips. This number of trips would have none to negligible cumulative effects on the operating conditions (i.e., level of service) of the freeways, major arterials, and minor arterials that serve the Project area. Regional and local roads in the Denver Metropolitan area would temporarily be affected during construction of the proposed Denver Basin Aquifer Facilities.

Construction of the aquifer distribution pipeline would vary by location and diameter of pipe, but would average approximately 25 to 35 days per mile for in-street construction. Well drilling would average 2 weeks per well. The three injection/recovery wells at each site would be drilled consecutively. The construction time of each well house would range from 30 to 60 days and would initially coincide with the well drilling activities. Installation of the aquifer distribution pipeline would result in temporary moderate cumulative impacts.

Construction of Conduit M is expected to be completed within a 2.5-year period (30 months). The potential impacts to transportation resulting from Alternative 10a are generally the same as those described for Conduit O under Alternative 8a. Major roadways affected by Conduit M would be I-25, I-76, Sheridan, Wadsworth, Washington, York, Federal, and Broadway.

The Denver Basin Aquifer Facilities would operate only during dry years or emergencies. The staff needed to operate these facilities would come from existing Denver Water Facilities when needed and use existing roads in the Denver Metropolitan area as access. Thus, no cumulative impacts to transportation resulting from operations and maintenance activities for the Denver Basin Aquifer Facilities are anticipated.

Access to public parks would not be changed under Alternative 10a. Traffic related to recreational activities at city parks may temporarily experience negligible to minor cumulative delays during construction due to an increased volume of construction-related traffic in localized areas.

Construction access would be obtained using existing roads in the area. The temporary cumulative impacts to traffic operations would be passenger vehicle delays due to queuing behind slower-moving construction equipment vehicles and higher than average volumes of commuter traffic during peak construction. The frequency and time duration of these traffic delays, and the numbers of people affected by them, pose negligible to minor cumulative impacts particularly in comparison with the existing traffic conditions and projected development in Denver County.

4.6.12.5 Alternative 13a with Reasonably Foreseeable Future Actions

The total environmental effects to transportation at Gross Reservoir under Alternative 13a are generally the same as those described for the Proposed Action with RFFAs, except with a shorter construction period (3.6 years or 43 months) and fewer vehicle trips per day.

The total environmental effects to transportation for the South Platte River Facilities and Conduit O are generally the same as those described above for Alternative 8a.

4.6.12.6 No Action Alternative with Reasonably Foreseeable Future Actions

Since no construction activities would occur under the No Action Alternative, no cumulative impacts to transportation resources are anticipated. Traffic associated with operations and maintenance of existing Denver Water facilities would remain unchanged. Anticipated population growth and land development in portions of the Project area will cumulatively generate additional traffic irrespective of the Moffat Project.

4.6.13 Air Quality

The affected environment for air quality is described for Current Conditions (2006) in Section 3.13. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to air quality are evaluated against Current Conditions (2006).

4.6.13.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Short-term air quality impacts for the Proposed Action are related primarily to on-site construction activities. Temporary off-site air quality impacts would include exhaust emissions from heavy-duty construction equipment, exhaust emissions from construction workers' vehicles and delivery vehicles, and fugitive dust emissions. If the Proposed Action is permitted, a general conformity analysis would be conducted prior to construction to ensure compliance with the National Ambient Air Quality Standards (NAAQS). Recommended mitigation measures and control plans for both fugitive dust and combustion emissions are discussed in Section 5.13.7.

Post construction activities associated with operations and maintenance of the Moffat Project facilities would contribute a small amount of regional air quality emissions. Additionally, many facilities would operate intermittently during dry years or emergencies. Long-term cumulative air quality impacts from the operation of Gross Reservoir are related primarily to emissions from visitor automobiles. Overall, these emissions are expected to be negligible, particularly in comparison with regional emissions associated with ongoing and projected development in the Project area.

4.6.13.2 Alternative 1c with Reasonably Foreseeable Future Actions

The total environmental effects to air quality at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (40,700 acre-feet [AF]). If Alternative 1c is permitted, a general conformity analysis would be conducted prior to construction to ensure compliance with NAAQS.

Construction activities associated with the new Leyden Gulch Reservoir site would create temporary emissions of dust and combustion products. It is possible that construction of Leyden Gulch Reservoir and other developments in the area may occur simultaneously resulting in localized short-term minor to moderate cumulative impacts on air quality. However, the other development projects in the area would also be required to implement control plans for fugitive dust and combustion emissions. County planning departments may also take steps to limit simultaneous development on adjacent parcels by limiting the number of construction permits issued in a given year.

4.6.13.3 Alternative 8a with Reasonably Foreseeable Future Actions

The total environmental effects to air quality at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (52,000 AF). If Alternative 1c is permitted, a general conformity analysis would be conducted prior to construction to ensure compliance with NAAQS.

For Alternative 8a, it was assumed that when the Board of Water Commissioners (Denver Water) acquires the gravel pits they would be completely mined and reclaimed for use as an empty water storage facility. Construction activities associated with Conduit O, the gravel pit pipelines, and the Advanced Water Treatment Plant would, however, create temporary emissions of dust and combustion products. Overall, cumulative air emissions effects are expected to be negligible to minor, particularly in comparison with regional emissions associated with existing and projected development in Adams County.

4.6.13.4 Alternative 10a with Reasonably Foreseeable Future Actions

The total environmental effects to air quality at Gross Reservoir under Alternative 10a would be the same as those described for Alternative 8a.

Construction activities associated with the Denver Basin Aquifer Facilities would create temporary emissions of dust and combustion products. Overall, cumulative air emissions effects are expected to be negligible to minor, particularly in comparison with regional emissions associated with previously developed areas and projected development in Denver County.

4.6.13.5 Alternative 13a with Reasonably Foreseeable Future Actions

The total environmental effects to air quality at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (60,000 AF). If Alternative 1c is permitted, a general conformity analysis would be conducted prior to construction to ensure compliance with NAAQS.

The total environmental effects to air quality for the South Platte River Facilities are the same as those described above for Alternative 8a.

4.6.13.6 No Action Alternative with Reasonably Foreseeable Future Actions

There are no ground-disturbing activities associated with the No Action Alternative; thus, no cumulative impacts to air quality are anticipated.

4.6.14 Noise

The affected environment for noise is described for Current Conditions (2006) in Section 3.14. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to noise are evaluated against Current Conditions (2006).

Short-term increases in ambient noise levels from construction activities are anticipated from the Moffat Project with RFFAs. These impacts would be temporary, localized, and typically limited to daylight hours. Other proposed developments in the Project area would similarly have temporary and localized increases in noise during construction. Simultaneous construction activity of Moffat Project components and other developments in the same area is unlikely, but would cause temporary and localized negligible to moderate cumulative increases in noise if it occurred. All projects would be required to comply with applicable county, State, and Federal standards and guidelines.

4.6.14.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Enlarging Gross Reservoir under the Proposed Action would require approximately 39 pieces of equipment operating over a 49-month (4.1 years) construction period, followed by operation of the dam and reservoir. The proposed construction activities associated with the enlargement of Gross Reservoir are not predicted to exceed relevant standards or guidelines. On-site construction noise may periodically exceed the U.S. Environmental Protection Agency (EPA) noise threshold of 70 A-weighted decibel scale (dBA) for public exposure (EPA 1974), but the public would not be exposed to these levels on a continuous basis. Noise impacts, including tree removal and localized blasting, are anticipated to be temporary and moderate during on-site construction.

Off-site construction-related noise is predicted from increased traffic using site access roads. Residential areas may be affected by noise from construction traffic during day-time hours, but not at night. The noise impacts from construction traffic would contribute to the overall background noise levels in the Gross Reservoir study area and are anticipated to be temporary and minor. Past regional population growth and development in the Front Range has mostly occurred east of the foothills, but has had some effect on the Gross Reservoir area. In addition to areas around the existing Gross Reservoir, the principal developments that have occurred are large-acre residential areas, roads, and a railroad. No new or proposed residential development is projected in the area that would create construction noise impacts and private development opportunities are limited since the reservoir is primarily surrounded by U.S. Forest Service (USFS) land and Boulder County Open Space. Since noise generated during Moffat Project construction activities and commuting traffic is not expected to exceed applicable standards or guidelines on a continuous basis, the temporary noise impacts would result in minor to moderate cumulative impacts. Post construction activities associated with operations and maintenance of the facilities at Gross Reservoir would contribute a negligible amount of noise to existing ambient conditions.

4.6.14.2 Alternative 1c with Reasonably Foreseeable Future Actions

The total environmental effects to noise at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (40,700 acre-feet [AF]) that would occur during a shorter construction time frame.

The proposed Leyden Gulch Reservoir and related facilities are expected to be completed within a 3.5-year (42 months) period. Construction activities associated with the new Leyden Gulch Reservoir site would create temporary moderate noise impacts. It is possible that construction of Leyden Gulch Reservoir and other developments in the area (transportation improvements and the future industrial/office redevelopment at the intersection of State Highway [SH] 72 and SH 93) may occur simultaneously resulting in localized short-term moderate cumulative impacts to noise. However, the other development projects in the area are likely to occur irrespective of the development of the reservoir and would also be required to comply with applicable standards and guidelines.

4.6.14.3 Alternative 8a with Reasonably Foreseeable Future Actions

The total environmental effects to noise at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (52,000 AF) that would occur during a shorter construction time frame.

For Alternative 8a, it was assumed that when the Board of Water Commissioners (Denver Water) acquires the gravel pits they would be completely mined and reclaimed for use as an empty water storage facility. However, construction activities associated with Conduit O, the gravel pit pipelines, and the Advanced Water Treatment Plant (AWTP) would create temporary moderate noise impacts. Noise associated with construction activity occurring within the urban portions of Conduit O would be negligible in the context of the Denver Metropolitan area. The rural portions of Conduit O are likely to be moderately affected by temporary construction noise than the more developed areas. Some of the Alternative 8a components, such as the AWTP and conduit pump stations, would be equipped with sound mitigating features. Additionally, the facilities would operate intermittently during dry years or emergencies. Noise impacts associated with truck traffic and increases in workforce related traffic would be intermittent and minor during this time period. Overall, cumulative noise effects are expected to be minor, particularly in comparison with the existing ambient noise levels and noise generated from existing and projected development in Adams County.

4.6.14.4 Alternative 10a with Reasonably Foreseeable Future Actions

The total environmental effects to noise at Gross Reservoir under Alternative 10a would be the same as those described for Alternative 8a.

Noise generated from the construction activity associated with the Denver Basin aquifer storage and recovery system is anticipated to be short-term and minor in the urban context of Denver. No water would be injected into the Denver Basin aquifers in years when the stored water is not used. Additionally, the deep wells require submersible pumps; therefore, pump noise generation during pump operation would be negligible. Noise associated with construction activity occurring within the urban portions of Conduit M would be negligible in the context of the Denver Metropolitan area. The more rural portions of Conduit M are likely to be moderately affected by temporary construction noise than the more developed areas. Three pump stations would be located along Conduit M. Each pump station would be enclosed in a building and would be equipped with sound mitigation features generating negligible noise during operation. Overall, cumulative impacts to noise are expected to be minor, particularly in comparison with the existing ambient noise levels and noise generated from existing and projected development in Denver County.

4.6.14.5 Alternative 13a with Reasonably Foreseeable Future Actions

The total environmental effects to noise at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (60,000 AF) that would occur during a shorter construction time frame.

The total environmental effects to air quality for the South Platte River Facilities are the same as those described above for Alternative 8a.

4.6.14.6 No Action Alternative with Reasonably Foreseeable Future Actions

There are no ground-disturbing activities and related construction noise associated with the No Action Alternative; thus, no cumulative impacts to noise are anticipated.

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4.6.15 Recreation

The affected environment for recreation is described for Current Conditions (2006) in Section 3.15. This cumulative impacts analysis evaluates the potential effects of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential effects to recreational activities, particularly boating and fishing, are evaluated against Current Conditions (2006).

4.6.15.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Gross Reservoir

Past regional population growth and development in the Front Range has mostly occurred east of the foothills, but has had some effect on the Gross Reservoir area. In addition to areas around the existing Gross Reservoir, the principal developments that have occurred are large-acre residential areas, roads, and a railroad. No new or proposed residential development is projected in the area and private development opportunities are limited since the reservoir is primarily surrounded by U.S. Forest Service land and Boulder County Open Space. The Proposed Action with RFFAs would have minor, if any, cumulative effects on recreation at Gross Reservoir. Impacts in the reservoir vicinity would be limited to the direct effects of increasing the size of the reservoir. Site specific impacts to recreational activities resulting from the expansion of Gross Reservoir are discussed in Section 5.15.

4.6.15.2 River Segments

Anticipated cumulative impacts vary by river segment, type of recreational activity, and by annual conditions (e.g., dry, average, or wet year). For example, on some streams there could be a moderate to major cumulative impacts on boating use, while fishing activity would generally not be impacted. There would be minor cumulative impacts to recreational activities during dry years. Therefore, total environmental impacts to recreation vary from minor to major, depending on the recreational activity, river segment, and annual conditions.

Recreation on numerous drainages would be affected by additional diversions or increases in flow by the Proposed Action with RFFAs. Several of these drainages provide a variety of recreational opportunities at the regional and local scale. These recreational opportunities include water dependent activities, such as boating and fishing, as well as other activities that are not dependent on water flows, such as mountain biking, hiking, and nature viewing. With respect to these activities, the presence of rivers and streams contributes to the visual setting in which they are taking place and subsequently to the overall recreation experience. Refer to Section 4.6.11 for a further discussion of the fisheries habitat and related impacts.

Fraser River

Under adequate water conditions, the Fraser Canyon segment offers a high quality boating experience. Some sources indicate that the optimum flow range for kayaks through Fraser Canyon is 400 to 700 cubic feet per second (cfs) (Hydrosphere 2003). The Grand County Stream Management Plan defines the optimum flow range as 400 to 900 cfs (Grand County 2010). Other sources indicate that the canyon segment is difficult to run when flows are less than 400 cfs (American Whitewater 2006). Typically, flows above 400 cfs only occur in May, June, and July in an average or wet year (Fraser River below Crooked Creek). For purposes of assessing potential impacts in the Environmental Impact Statement, the flow range provided in the Grand County Stream Management Plan was utilized.

Over the 45-year period of record that was evaluated, the average flow under Current Conditions (2006) through Fraser Canyon is 291 cfs in May, 492 cfs in June, and 177 cfs in July (Table H-1.49). In a wet year, the average monthly flow is 542 cfs in May, 1,051 cfs in June, and 408 cfs in July. Therefore, a wet year offers a more extended season (in excess of 60 days) with opportunities for an adventurous boating experience during the high flows of May through July.

By the year 2032 with implementation of the Proposed Action with RFFAs, flows in the Fraser River would be diminished. For the Fraser Canyon segment, the average normal year flow in June would drop from 492 to 388 cfs, representing a 21% depletion. A more detailed comparison is provided in Table 4.6.15-1. In an effort to characterize a "normal" year and compare Current and Future conditions, one year per decade over the period used for modeling in the Platte and Colorado Simulation Model (PACSM) (1946 through 1991) was randomly selected for further review. The five years selected do not represent either unusually wet or dry years.

Table 4.6.15-1
Fraser River below Crooked Creek, Current Conditions (2006) Versus Proposed Action with RFFAs (2032), Number of Days at a Given Flow Rate for Kayaking*

Year	Optimum (400-900 cfs)	
	Current Conditions (2006)	Proposed Action with RFFAs (2032)
1957	41	38
1966	0	0
1975	12	4
1987	23	10
1991	11	6
1946-1991	812	632

Source: PACSM Results (Node 2810).
Notes:
*No flow range information is shown for rafting for this river segment due to lower use levels.
Years were randomly selected to represent normal Current Conditions (2006).
1946-1991 is a summary of the 45 year period used for PACSM.

As shown in Table 4.6.15-1, flow conditions vary widely, even when those years not considered as extremely wet or dry are excluded. For example, in 1966 there were no flows above 400 cfs; therefore, conditions would not have supported boating use that year under both Current Conditions (2006) and 2032 conditions. In contrast, the 1987 baseline year had 23 days above the 400 cfs flow level under Current Conditions (2006), which would drop to 10 days with implementation of the Proposed Action with RFFAs. In years with hydrologic conditions similar to 1987, there would be a substantial reduction in days with optimum flows resulting in major adverse cumulative effects. In each of the other years shown in Table 4.6.15-1, the number of days with flows in the optimum range would also decline, though not by as many days as under 1987 conditions. The number of reduced days of optimum flows in each of the other years ranges from 3 in 1957 to 8 in 1975.

Implementation of the Proposed Action with RFFAs would also reduce the number of days in average years with flows above 700 cfs, thus reducing the number of days when the river could be used by more advanced kayakers.

A review of flow change effects over the course of the full 45 years of record (1946 through 1991) indicates that implementation of the Proposed Action with RFFAs would result in a total reduction of 180 days when flows fall within the optimum range of 400 to 900 cfs. Under Current Conditions, 812 days fall within the optimum flow range compared to 632 days under Future Conditions. Considering a 45-year period of record, this represents a drop in available use days at the optimum flow range of approximately 5 days per year on average, a reduction of approximately 20% annually.

In wet years, the Proposed Action with RFFAs would reduce the average monthly flow in May and June by approximately 13% in both months, as compared to Current Conditions (2006). The resulting average monthly flows would be 470 cfs in May and 912 cfs in June, compared to 542 cfs and 1,052 cfs under Current Conditions. The impact on boating use, however, would be minor. Under both Current and 2032 conditions, wet years produce an extended boating season, in excess of 60 days with flows above 400 cfs, and with a similar pattern of flows. Most days that are boatable in wet years for both Current and 2032 conditions would occur on days when flows are in excess of 700 cfs. The main difference is that the very highest flows would be consistently reduced.

The Proposed Action with RFFAs would have no cumulative impacts on boating in dry years.

Overall, Future Conditions would contribute to major, long-term adverse cumulative impacts on boating on the Fraser River. These impacts would include a reduction in the average number of days when boating could occur within the optimum flow range in the Fraser Canyon, as well as the length of the boating season. There would also be a reduction in the highest flows, resulting in fewer days on average with flows in excess of 700 cfs. However, these higher flow levels would continue to occur in wet years. Although there are low use levels for boating in this segment, an average loss of 4 days per year to boat within optimum flow levels represents a loss of approximately 20% of available use days. In some years, the number of days lost would be higher creating major, long-term cumulative impacts.

Snowmaking at local ski resorts occurs primarily from October through December. PACSM results indicate that there would be small depletions (1-2%) occurring during these months under the 2032 conditions beyond the Current Conditions (2006). Therefore, the Proposed Action and RFFAs would not affect snowmaking activities.

Impacts to fishing are almost entirely dependent on the level of effect flow modifications would have on the health on the fishery. As described in Section 4.6.11, cumulative effects to species composition, population levels and other factors related to the health of the fishery are expected to be minor. Flow reductions during periods of higher flows are not expected to adversely affect the quality of the fishing experience. In some cases, flow reductions during periods of high flow may actually provide a minor beneficial effect to the quality of fishing. Reduced flows can expose areas along the river that are typically inundated under higher flows, and would consequently make them accessible to anglers. Additionally, fish tend to lose energy while fighting higher energy flows, thus a reduced flow may make them more active. The Proposed Action with RFFAs would not contribute to cumulative impacts on fishing in dry years. Overall, the Project with RFFAs would have negligible to minor cumulative effects on fishing in the Fraser River.

Section 4.6.11 states the Proposed Action with RFFAs would have minor adverse cumulative impacts on the fish communities in North Fork Ranch Creek. There may be associated minor adverse cumulative impacts on the quality of the recreation fishing experience in this stream.

As indicated in Section 4.6.17, in dry years there would be adverse cumulative impacts to visual aesthetics of the Fraser River above Crooked Creek as a result of the Proposed Action with RFFAs. The setting in which people recreate along the Fraser River contributes to the overall recreation experience. As such, these visual impacts may also adversely impact recreation as a result of a diminishment of the quality of the setting during times of flow reductions.

Williams Fork River

No cumulative impacts are expected to occur to the quality of the fishing experience along the Williams Fork River as a result of the Proposed Action with RFFAs.

Colorado River

The Colorado River downstream of Kremmling through Gore Canyon is a heavily used recreational area for a variety of boating uses. American Whitewater indicates that a desirable flow range for rafting extends from a minimum of 700 cfs to a maximum of 2,000 cfs (American Whitewater 2006). The Grand County Stream Management Plan identified 800 to 1,250 cfs as the optimum flow range for rafts (Grand County 2010). The flow range presented in the Grand County Stream Management Plan was used to assess cumulative impacts to rafting and kayaking.

Under Current Conditions (2006) in normal years, the Colorado River below Kremmling reaches optimum flows for boating during much of the peak season from May through September, and can far exceed optimum levels in wet years.

By the year 2032 when the Proposed Action with RFFAs would be fully implemented, flows in the Colorado River would be diminished. More specifically, average monthly flows would drop from 4 to 18% during the May-September prime use season (Table H-1.60). However, on average, the number of days when flows fall within the desirable range of 800 to 1,250 cfs for kayaking and rafting would increase slightly, rising from 85 days per year under Current Conditions to 87 with the Proposed Action with RFFAs. In any given year, however, these changes would be more notable. For example, PACSM results for 1966 and 1975 show that optimum flow conditions would increase by 12 days in each of these years with implementation of the Project with RFFAs. In 1991 conditions, however, the number of days with optimum flows would decrease by 34 days.

Over the period of record, the number of days with flows falling in the optimum range would increase by 93 days. On average, the number of days with optimum flows would increase from 85 days under Current Conditions to 87 days with implementation of the Proposed Action with RFFAs, an increase of approximately 2 days per year. The distribution would change in any given year, however, increasing in some years and dropping in others. The overall cumulative effects on boating would be minor.

The cumulative effects on boating further downstream (below Pumphouse), which has similar or lower optimum flow requirements (Grand County 2010), would also be minor.

The Grand County Management Plan also identified a higher optimum flow range for kayaking this river segment, which ranged from 1,200 to 1,400 cfs. These flows occur much less frequently than the ranges shown in Table 4.6.15-2, with 871 days over the period of record under Current Conditions. This would drop to 573 days with implementation of the Proposed Action with RFFAs.

Table 4.6.15-2
Colorado River below Kremmling, Current Conditions (2006) Versus Proposed Action with RFFAs (2032), Number of Days at a Given Flow Rate for Rafting and Kayaking

Year	Optimum (800-1,250 cfs)	
	Current Conditions (2006)	Proposed Action with RFFAs (2032)
1957	69	77
1966	50	62
1975	96	108
1987	115	93
1991	69	35
1946-1991	3,844	3,937

Source: PACSM Results (Node 5020).
Notes:
Years were randomly selected to represent normal pre-Project conditions.
1946-1991 is a summary of the 45-year period used for PACSM.

Although the Proposed Action with RFFAs would divert a larger volume in wet years than in average years; the percent of flow reduction declines slightly because of the higher overall flows that occur in these years. For the wet years that were evaluated, comparing Current Conditions (2006) to implementation of the Proposed Action with RFFAs, the average monthly flow change during the period May through September ranges from no change in July to a 16% decrease in May (Table H-1.60).

The Project would not contribute to cumulative impacts on boating in dry years.

Overall, the Project with RFFAs would have minor cumulative impacts on boating use on the Colorado River. No cumulative impacts to fishing on the Colorado River are anticipated.

Blue River

Two segments were considered in the analysis, including the segment between Dillon and Green Mountain reservoirs and the segment downstream of Green Mountain. The Grand County Stream Management Plan identified an optimum flow range of 600 to 1,000 cfs for kayaking and 700 to 1,400 cfs for rafting (Grand County 2010). The Grand County flow ranges were used to determine the number of days with optimum flows under both Current Conditions (2006) and with Project (2032) conditions for both segments. This information is summarized in a series of tables that follow.

As indicated in Table 4.6.15-3, the number of days when flows are within the optimum range for kayaking decreases with implementation of the Proposed Action with RFFAs. These decreases range from 1 day in 1991 to a high of 13 days in 1957. In one year (1987), days with optimum flows would increase by 1 day. Over the entire 45-year modeling period, the number of days with flows falling within the optimum range would decrease from 581 to 419 days, or from 13 days on average annually to 9 days.

Table 4.6.15-3
Blue River Near Boulder Creek, Current Conditions (2006) Versus Proposed Action with RFFAs (2032), Number of Days at a Given Flow Rate for Boating

Year	Optimum (600-1,000 cfs) Kayaking		Optimum (700-1,400 cfs) Rafting	
	Current Conditions (2006)	Proposed Action with RFFAs (2032)	Current Conditions (2006)	Proposed Action with RFFAs (2032)
1957	32	19	40	11
1966	4	0	0	0
1975	9	2	27	6
1987	29	30	46	28
1991	5	4	10	6
1946-1991	581	419	835	533

Source: PACSM Results (Node 4500).
Notes:
Years were randomly selected to represent normal pre-Project conditions.
1946-1991 is a summary of the 45-year period used for PACSM.

Similar results would occur for rafting, with a decrease in the number of days with optimum flows ranging from 29 days in 1957 to no change in 1966. Over the entire 45-year modeling period, the number of days with flows falling within the optimum range would decrease from 835 to 533 days, and the average number of days annually that fall within the optimum range would drop from 19 to 12 days.

This overall cumulative effect on boating use in the segment above Green Mountain Reservoir would be adverse and major.

The lower segment below Green Mountain Reservoir was analyzed in a similar manner. These results are shown in Table 4.6.15-4. As in the upper segment, the number of days when flows are within the optimum range for kayaking decreases with implementation of the Proposed Action with RFFAs. These decreases range from 4 days in 1987 to a high of 35 days in 1991. In one year (1975), days with optimum flows would increase by 3 days. Over the entire 45-year modeling period, the number of days with flows falling within the optimum range would decrease from 1,960 to 1,679, a reduction of 281 days. On average, this represents an annual loss of 7 days, dropping from an average of 44 days under Current Conditions (2006) to 37 days with implementation of the Project with RFFAs. For rafting, a similar pattern emerges, with an average annual reduction in the number of days with optimum flows dropping from 35 to 28 days. This degree of change would also represent a major adverse cumulative impact on boating use.

Table 4.6.15-4
Blue River below Green Mountain Reservoir, Current Conditions (2006) Versus Proposed Action with RFFAs (2032), Number of Days at a Given Flow Rate for Boating

Year	Optimum (600-1,000 cfs) Kayaking		Optimum (700-1,400 cfs) Rafting	
	Current Conditions (2006)	Proposed Action with RFFAs (2032)	Current Conditions (2006)	Proposed Action with RFFAs (2032)
1957	58	47	57	47
1966	44	32	36	26
1975	37	40	32	27
1987	49	45	43	38
1991	41	6	34	5
1946-1991	1,960	1,679	1,583	1,273

Source: PACSM Results (Node 4650).
Notes:
Years were randomly selected to represent normal pre-Project conditions.
1946-1991 is a summary of the 45-year period used for PACSM.

No cumulative impacts are expected to occur to the quality of the fishing experience along the Blue River as a result of the Proposed Action with RFFAs.

South Boulder Creek

Segments above and below Gross Reservoir receive some use by expert kayakers able to handle the Class IV+ whitewater that occur along these portions of the creek. The upper South Boulder Creek segment (Pinecliffe to Gross Reservoir) would be affected by the Proposed Action with RFFAs through increased flows, primarily during the summer months, with the greatest change occurring in June when average monthly flows would increase by 20%. Although the number of days with very high flows would increase during June, possibly curtailing use on some days by all but the most expert of boaters, the overall cumulative impacts would be to shift use to periods later in the season. Increased flows in July and later in the summer would extend the boating season on this segment and would therefore not result in a loss of boating opportunities. The overall impacts on boating resulting from increased flows would be minor to moderate and beneficial.

The lower South Boulder Creek segment (Gross Reservoir through Eldorado Canyon) is an expert kayak run that would be influenced by the Proposed Action with RFFAs. At the South Boulder Creek near Eldorado Springs gage, average flows would be slightly reduced during the boating season as a result of the Proposed Action with RFFAs. Monthly average flows would drop by 6% in May and 5% in June, reaching 148 cfs and 266 cfs, respectively (Table H-1.67). One source indicates that the optimum flow range for this segment is 150 to 300 cfs (Southwest Paddler 2007). The cumulative impacts on boating use would be minor.

It is expected that there would be minor adverse impacts to the quality of fishing along portions of upper South Boulder Creek from the Moffat Tunnel to Gross Reservoir. Sections 4.6.11 and 5.11 suggest there is expected to be a long-term effect that would result in a decrease of fish habitat availability along this stretch. The reductions in habitat availability for adult brook and rainbow trout along this segment as a result of the Proposed Action with RFFAs may impact fish populations compared to Current Conditions (2006). A potential reduction in the fish habitat availability would create negative cumulative impacts on the quality of the fishing experience.

There may be a minor beneficial cumulative effect to the fishing experience on lower South Boulder Creek below Gross Reservoir as a result of higher density fish populations due to reduced flows during runoff, particularly during the peak runoff month of June, as well as increased flows during winter months. Both of these differences would tend to provide more favorable conditions for fish. As suggested in Sections 4.6.11 and 5.11, increases in habitat availability for rainbow trout indicate that the Proposed Action with RFFAs would have a beneficial impact on fish populations on this segment of South Boulder Creek, compared to Current Conditions (2006). Flow reductions during periods of high flow may actually provide a minor beneficial cumulative effect to the quality of fishing (refer to the Fraser River discussion).

North Fork South Platte River

This river segment includes two reaches that receive boating use: one extending from Bailey to Pine and the second reach extending from Buffalo Creek to the confluence with the mainstem South Platte River.

The 10.5-mile Bailey to Pine reach is a combination of Class IV and V rapids. With implementation of the Proposed Action with RFFAs, this reach would see a major increase in flows during the months of May through August, reaching the highest monthly average flow of 490 cfs in June. These increases would have a significant positive cumulative impact on boating use, prolonging optimum boating flows throughout the summer. In September, the flows would increase by 49%, from 260 to 388 cfs.

The Buffalo Creek to mainstem South Platte River reach is a combination of Class III and IV whitewater. The minimum recommended flow level for boating is approximately 400 cfs (American Whitewater 2006). These flows generally occur only during the months of May and June. On average, the Proposed Action with RFFAs would increase flows in this segment, increasing monthly average flows from 399 cfs in June to 490 cfs. The flow changes would have major beneficial cumulative impacts on boating use.

At the North Fork South Platte River below Geneva Creek gage, the Proposed Action with RFFAs would increase flows during the summer months, with the greatest increase occurring in July when the average monthly flow would increase by 49% as compared to Current Conditions. Flows would increase during July from 255 to 380 cfs. This increase may shift the timing of use somewhat during the summer season, but overall would have major beneficial cumulative impacts on boating use.

The increases in flow would not have a major cumulative impact on the quality of fishing along the North Fork South Platte River. Flow increases may make it slightly more difficult to fish during periods of high flow, particularly in May, but the overall cumulative impacts would be minor, resulting in a shift in the period of use to later in the season.

South Platte River

Some kayaking occurs on the South Platte River downstream of the confluence with the North Fork South Platte to Strontia Springs Reservoir. During the period of highest flows (May and June) average monthly flows would be reduced by 8% and 12%, respectively (Table H-1.72). This would be a minor degree of change and a minor adverse effect for boaters who enjoy higher flow levels. Later in summer, the degree of flow change increases, rising to a maximum reduction of 27% in August when average monthly flows would drop from 227 to 165 cfs in a normal year. American Whitewater (2006) indicates that 150 cfs is the minimum flow level for kayaks in the South Platte River above Strontia Springs Reservoir. These later season flow reductions would have a minor to moderate adverse cumulative effect on boating use.

There may be a minor beneficial effect to the fishing experience on the South Platte River as a result of slightly reduced flows. Flow reductions during periods of high flow may actually provide a minor beneficial effect to the quality of fishing (refer to the Fraser River discussion).

4.6.15.3 Alternative 1c with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to recreational resources at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion of Gross Reservoir (40,700 acre-feet [AF]).

Leyden Gulch Reservoir Site

The recreational status of the Leyden Gulch Reservoir site would not change with construction of a reservoir; it would remain closed to public uses, including recreation. As such, there would be no cumulative effects to recreation at or near the Leyden Gulch Reservoir site.

River Segments

Cumulative impacts to all river segments under Alternative 1c would be similar to those described for the Proposed Action with RFFAs.

4.6.15.4 Alternative 8a with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to recreational resources at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion of Gross Reservoir (52,000 AF).

South Platte River Facilities

Recreational use of gravel pit storage sites would not be allowed under Alternatives 8a. This would represent a direct impact to recreational opportunities in the Project area as discussed in Section 5.15. However, given the regional impetus for open space preservation and parks development, this impact would not result in major cumulative effects to overall recreational opportunities in the analysis area.

Construction of the diversion structure across the South Platte River would result in additional cumulative impacts to recreational users during seasonal flow reductions. Cumulative impacts would consist of diminished recreational experience due to unnatural features or obstructions and potential safety hazards at lower flows when boaters, in particular, are required to more precisely navigate around natural and unnatural obstructions. The cumulative effects to recreational use on the South Platte River would be minor overall, but long term.

Should construction of the conduit overlap with other land-based activities, such as lane closures or riverside construction activities, there could be minor short-term cumulative impacts to recreation. However, in general, the impacts of the conduits are expected to result in minor cumulative effects to recreation resources in the analysis area. Due to the hydrology modeling requirements, the cumulative effects of water-based actions on recreation resources along the conduit alignments are incorporated into the direct and indirect impacts discussion in Section 5.15, but are also predicted to be minor.

River Segments

Cumulative impacts to all river segments under Alternative 8a would be similar to those described for the Proposed Action with RFFAs.

4.6.15.5 Alternative 10a with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to geologic resources at Gross Reservoir would be the same as those described for Alternative 8a with RFFAs.

Denver Basin Aquifer Facilities

Well clusters and pump houses associated with the Denver Basin Aquifer Facilities under Alternative 10a would be located to avoid established park uses and amenities (e.g., picnic pavilions or playgrounds). As such, there would be minor overall cumulative effect to number or types of recreational opportunities offered within the City and County of Denver parks system. Each well cluster and pump house would remove approximately 0.5 acre of parkland from use. The anticipated population growth and ongoing urbanization and infill development efforts, when combined with the well cluster structures in the park, may result in minor cumulative impacts to recreational experience at these properties. Due to the hydrology modeling requirements, the cumulative effects of water-based actions on recreation resources throughout the Denver Basin aquifer storage system are incorporated into the direct and indirect impacts discussion in Section 5.15.

Should construction of the conduit overlap with other land-based activities, such as lane closures or riverside construction activities, there could be minor short-term cumulative impacts to recreation. However, in general, the impacts of the conduits are expected to result in minor cumulative effects to recreation resources in the analysis area. Due to the hydrology modeling requirements, the cumulative effects of water-based actions on recreation resources along the conduit alignments are incorporated into the direct and indirect impacts discussion in Section 5.15, but are also predicted to be minor.

River Segments

Cumulative impacts to all river segments under Alternative 10a would be similar to those described for the Proposed Action with RFFAs.

4.6.15.6 Alternative 13a with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to geologic resources at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (60,000 AF).

South Platte River Facilities

Cumulative impacts would be the similar to those described for Alternative 8a. This alternative, however, would require the conversion of agricultural water rights to municipal or other non-irrigation uses. As discussed in Section 5.15, because the areas that would be removed from agricultural production due to agricultural water right transfers do not support existing recreational uses, the conversion of agricultural water rights would have no impact on recreational opportunities; therefore, there would be no cumulative impacts to recreation resources as a result of this Project component.

Should construction of the conduit overlap with other land-based activities, such as lane closures or riverside construction activities, there could be minor short-term cumulative impacts to recreation. However, in general, the impacts of the conduits are expected to result in minor cumulative effects to recreation resources in the analysis area. Due to the hydrology modeling requirements, the cumulative effects of water-based actions on recreation resources along the conduit alignments are incorporated into the direct and indirect impacts discussion in Section 5.15, but are also predicted to be minor.

River Segments

Cumulative impacts to all river segments under Alternative 13a would be similar to those described for the Proposed Action with RFFAs.

4.6.15.7 No Action Alternative with Reasonably Foreseeable Future Actions

Under the No Action Alternative, the Board of Water Commissioners (Denver Water) would continue to operate their existing system until it reaches Full Use of the Existing System. The effects of the additional diversions associated with Full Use of the Existing System are discussed in the sections that follow. In addition to increased diversions, other strategies would also be required under the No Action Alternative to help meet water demand. These strategies and their potential effects are discussed at the end of this section.

River Segments

There are no ground-disturbing activities under the No Action Alternative, but stream flow modifications would occur due to increasing demands and Denver Water making Full Use of the Existing System. These effects are described below.

Fraser River below Crooked Creek

For the Fraser Canyon segment, the average normal year flow in June would drop from 492 cfs under Current Conditions to 456 cfs, representing a 7% change. A more detailed comparison is provided in Table 4.6.15-5. In an effort to characterize a "normal" year and compare pre- and post-Project conditions, 5 years, 1 year per decade over the period used for modeling in the PACSM (1946 through 1991), were randomly selected for further review. The 5 years selected do not represent either unusually wet or dry years. See Section 4.6.15.1 for a discussion of optimum flow rates.

Table 4.6.15-5
Fraser River below Crooked Creek, Current Conditions (2006) Versus the No Action Alternative with RFFAs (2032), Number of Days at a Given Flow Rate for Kayaking*

Year	Optimum (400-900 cfs)	
	Current Conditions (2006)	No Action Alternative with RFFAs (2032)
1957	41	37
1966	0	0
1975	12	7
1987	23	23
1991	11	12
1946-1991	812	756

Source: PACSM Results (Node 2810).
Notes:
*No flow range information is available specifically for rafting for this river segment.
Years were randomly selected to represent normal pre-Project conditions.
1946-1991 is a summary of the 45-year period used for PACSM.

As shown in Table 4.6.15-5, flow conditions vary widely, even when those years not considered as extremely wet or dry are excluded. For example, in 1966 there were no flows above 400 cfs; therefore, conditions would not have supported boating use that year under both Current Conditions (2006) and No Action conditions. In contrast, the 1957 baseline year had 41 days above the 400 cfs flow level under Current Conditions (2006), which would drop to 37 days under the No Action Alternative. In years with hydrologic conditions similar to 1957 and 1975, there would be a reduction in days with optimum flows and a moderate adverse effect. In each of the other years shown in Table 4.6.15-5, the number of days with flows in the optimum range would stay the same or show a minor increase (1991).

A review of flow change effects over the course of the full 45 years of record (1946 through 1991) indicates the No Action Alternative would result in a total reduction of 56 days when flows fall within the optimum range of 400 to 900 cfs. Under Current Conditions, 812 days fall within the optimum flow range compared to 756 days under the No Action Alternative. This represents a drop in available use days at the optimum flow range of approximately 1 day per year on average. Overall, this would represent a moderate adverse effect on boating.

Colorado River

Under Current Conditions (2006) in normal years, the Colorado River below Kremmling reaches optimum flows for boating during much of the peak season from May through September, and can far exceed optimum levels in wet years. See Section 4.6.15.1 for a discussion of optimum flow rates.

The No Action Alternative would diminish flows in the Colorado River. More specifically, average monthly flows would drop from 4% to 17% during the May-September prime use season, with the greatest monthly decline occurring in June (Table H-1.6). However, on average, the number of days when flows fall within the desirable range of 800 to 1,250 cfs for boating would increase slightly, rising to 85 days per year under Current Conditions to 87 days under the No Action Alternative. In any given year, however, these changes would be more notable. For example, PACSM results for 1966 show that optimum flow conditions would increase by 14 days with the No Action Alternative, while in 1991 conditions, the number of days with optimum flows would decrease by 34 days. Over the entire period of record, the number of days with optimum flows would increase by 89 days. Overall, the effect on boating use would be minor to moderate and beneficial.

Blue River

As indicated in Table 4.6.15-6, the number of days when flows are within the optimum range for kayaking, using the gauging station near Boulder Creek decreases under the No Action Alternative compared to Current Conditions. See Section 4.6.15.1 for a discussion of optimum flow rates.

Table 4.6.15-6
Colorado River below Kremmling, Current Conditions (2006) Versus the No Action Alternative with RFFAs (2032), Number of Days at a Given Flow Rate for Boating

Year	Optimum (800-1,250 cfs)	
	Current Conditions (2006)	No Action Alternative with RFFAs (2032)
1957	69	35
1966	50	64
1975	96	105
1987	115	91
1991	69	35
1946-1991	3,844	3,933

Source: PACSM Results (Node 5020).
Note:
1946-1991 is a summary of the 45-year period used for PACSM.

The total number of days over the period of record drops from 581 days under Current Conditions to 360 days under the No Action Alternative. On average, this equals a reduction of 5 days per year when flows fall within the optimum range. Considering 5 years as representative average years (i.e., years that were not considered as exceptionally wet or dry), Table 4.6.15-7 demonstrates that the No Action Alternative would consistently reduce the number of days with optimum flows, with the greatest reduction occurring in 1957 (29 days) to 3 days in 1991.

Table 4.6.15-7
Blue River Near Boulder Creek, Current Conditions (2006) Versus the No Action Alternative with RFFAs (2032), Number of Days at a Given Flow Rate for Boating

Year	Optimum (600-1,000 cfs)		Optimum (700-1,400 cfs)	
	Current Conditions (2006)	No Action Alternative with RFFAs (2032)	Current Conditions (2006)	No Action Alternative with RFFAs (2032)
1957	32	3	40	0
1966	4	0	0	0
1975	9	3	27	7
1987	29	21	46	23
1991	5	2	10	1
1946-1991	581	360	835	472

Source: PACSM Results (Node 4500).
Note:
1946-1991 is a summary of the 45-year period used for PACSM.

Similar results are shown in Table 4.6.15-7 for rafting, which has an optimum flow range of 700 to 1,400 cfs. Over the period of record, the number of days with optimum flows would drop from 835 to 472 days, or by approximately 10 days per year on average. Considering only the 5 representative years, the reduction in the number of days with optimum flows would range from 40 days in 1957 to none in 1966.

Similar results would occur further downstream below Green Mountain Reservoir.

Overall, the degree of change resulting from the No Action Alternative can be considered a major adverse, long-term impact on recreational boating.

No impacts are expected to occur to the quality of the fishing experience along the Blue River as a result of the No Action Alternative.

South Boulder Creek

Above Gross Reservoir the No Action Alternative would increase flows in June by approximately 6% in an average year as compared to Current Conditions, and by 10% in July. The overall annual effect on flows would be an increase of 5%. The impact on boating would be minor and beneficial.

Minor flow changes would also occur on the upper portion of South Boulder Creek downstream of Gross Reservoir (above the South Boulder Diversion Canal), resulting in a 2% reduction in May and June, and an annual reduction of 1% (Table H-1.67). The overall impact on boating would be negligible.

North Fork South Platte River

The No Action Alternative would substantially increase flows compared to Current Conditions, resulting in a similar beneficial impact as was described for the Proposed Action with RFFAs.

4.6.15.8 Depletion of the Strategic Water Reserve Strategy

While the action alternatives would meet an additional 18,000 AF/yr of demand beyond Full Use of the Existing System, the No Action Alternative would have to rely on some combination of utilizing the Strategic Water Reserve and imposing mandatory restrictions to meet additional demands during drought sequences. The implementation of using the Strategic Water Reserve in combination with mandatory restrictions would be less intense than if either strategy were implemented alone; however, it may still have an effect on recreation.

Reservoirs

The contents of Williams Fork Reservoir and Wolford Mountain Reservoir would be relatively unaffected by the increased demand in the No Action Alternative. There would be very few and relatively small differences in operations in most months. Without additional storage, Denver Water would rely more heavily on their South Platte River supplies and Strategic Water Reserve to meet a higher demand, particularly during droughts. As such, reductions in reservoir contents in Antero, Eleven Mile Canyon, and Cheesman reservoirs under the No Action Alternative would be greater than reductions associated with all other alternatives, for all months on average. These reductions may have a moderate impact on recreation at each facility due to lower water levels. Lowered water levels would limit shoreline recreation activities, such as fishing, and may render boat ramps inoperable. The lower water levels would also have a moderate adverse impact on the recreational experience for other activities, such as hiking, camping, and day use due to the potential unsightly nature of reduced water levels during peak use periods.

Reductions in Dillon Reservoir contents under the No Action Alternative would almost always be greater than the reductions associated with all other alternatives, for all months and for average, dry, and wet conditions. This is because without additional storage on line, Denver Water would rely heavily on their Blue River supplies and Strategic Water Reserve to meet a higher demand, particularly during droughts. During droughts, Dillon Reservoir would be used more heavily than under Full Use of the Existing System and the action alternatives, and would be drained to the minimum active content level. This would have a moderate adverse impact on recreation by limiting shoreline recreation activities, such as fishing, and may render boat ramps inoperable. Boating, and associated organized boating events, are highly popular activities at Dillon Reservoir. Water levels below 8,971 feet render the boat ramp at Dillon Reservoir inoperable and water levels below 9,009 feet render the boat ramp at Frisco inoperable (Denver Water 2008a). The lower water levels would also have a moderate adverse impact on the recreational experience for other activities, such as hiking, camping, and day use due to the potential unsightly nature of reduced water levels during peak use periods.

The No Action Alternative is the only alternative in which Gross Reservoir would have lower contents than the Full Use of the Existing System scenario because Gross Reservoir is enlarged in all other scenarios and has significantly greater capacity. Gross Reservoir average end-of-month contents would be lower in some months. Gross Reservoir would be drained to the minimum pool more frequently under the No Action Alternative than under Full Use of the Existing System and the action alternatives. The maximum monthly average end-of-month reservoir elevation change would be a decrease of 5 feet in an average year, a decrease of 1 foot in a dry year, and a decrease of 14 feet in a wet year. Decreases of this magnitude would have a moderate adverse impact on recreation by limiting shoreline recreation activities, such as fishing, which are particularly popular at Gross Reservoir. Car top boating would likely also be impacted as it would make access to the waterline more difficult. The lower water levels would also have a negative impact on the recreational experience for other activities, such as hiking, camping, and day use due to the potential unsightly nature of reduced water levels during peak use periods.

4.6.15.9 Combination Strategy

As related to recreation at municipal parks, pools, golf courses, and other areas where water is required, Denver Water has described emergency water use restrictions that may be instituted as part of its drought response that would likely be part of the combination strategy. During a Stage 1 drought, only voluntary measures are suggested by water users. During a Stage 2 drought, government agencies are restricted to watering only 2 days per week during the summer use period, and watering is prohibited altogether during fall and winter. The watering of turf areas heavily used by the community, such as athletic and playing fields, and tees and greens at golf courses, as well as government-owned public parks, is not prohibited, but must be conducted without waste of water. The operation of outdoor waterfall and fountains and misting devices is prohibited. This would likely result in fewer visitors to parks and recreation areas with fountains due to the reduced visual appeal and overall park experience. There would also likely be fewer visitors to parks that operate "spray parks" as these would non-operational due to the restrictions. Response to Stage 3 drought conditions are somewhat more stringent. The watering of turf areas heavily used by the community such as athletic and playing fields is not prohibited, but shall be limited to Tuesdays and Fridays and irrigation of such fields shall be accomplished without waste of water. The operation of existing outdoor fountains or waterfalls that spray water into the air is also prohibited and no new outdoor fountains or waterfalls may be put into operation during a Stage 3 drought response. Additionally, the operation of outdoor misting devices is prohibited. While the filling of single-family residential pools is prohibited, the operation of other pools, such as pools at municipal water parks, would be permitted. Response to a Stage 3 drought would also likely have a moderate adverse impact to recreation resulting in fewer visitors to parks and recreation areas. With the reduced watering schedule, it is likely that the quality of heavily used public turf areas would decline over time and result in a reduced visual appeal. Additionally, this response would likely result in fewer visitors to parks and recreation areas with fountains due to the reduced visual appeal and overall park experience. There would also likely be fewer visitors to parks that operate "spray parks" as these would non-operational due to the restrictions.

Imposing restrictions would allow Denver Water to decrease bypass flows on the West Slope, which would increase the amount physically available for Denver Water to divert. If Denver Water diverts additional water due to decreased bypass flows, then stream flows would decrease on the West Slope. In addition, stream flow could slightly decrease in dry years if greater restrictions were imposed because less water would be released from storage.

Imposing restrictions would generally have the effect of preserving more of the Strategic Water Reserve; therefore, storage contents in Denver Water's reservoirs would likely be higher during a drought. Whether storage contents are higher depends on several factors. The amount and location of water reserved in storage would vary depending on the severity and duration of restrictions imposed, on storage conditions in Denver Water's North and South systems, and on hydrologic conditions. Since storage contents could be higher with restrictions, after a drought Denver Water's diversions into storage could be less and stream flows could increase for a short duration after Denver Water's reservoirs refill. However, this would not occur if a reservoir is drained even with restrictions in place. Conversely, with greater restrictions, during a drought stream flows would be less in some streams as Denver Water would decrease its releases from storage and decrease bypass flows. In summary, if mandatory restrictions were imposed in combination with depleting the Strategic Water Reserve, the following hydrologic impacts are likely to occur:

- Stream flows would decrease if bypass flows are decreased. For example, Denver Water would divert additional water from the Fraser River in dry years if bypass flows are reduced. This applies to several locations in the Fraser River Basin, the Blue River below Dillon Reservoir, and along the South Platte River below Eleven Mile Canyon Reservoir and Cheesman Reservoir, and at the Old Last Chance Ditch Diversion.
- Stream flows would increase along South Boulder Creek above Gross Reservoir if bypass flows in the Fraser River Basin are decreased since more water would be diverted through Moffat Tunnel.

- Stream flows could increase below Williams Fork Reservoir if additional releases are required to replace out-of-priority diversions at Dillon Reservoir or through Moffat Tunnel if bypass flows are reduced.
- Following a drought, stream flows could be higher for a short duration if Denver Water refills its reservoirs sooner. However, this would not occur if a reservoir is drained even with restrictions in place.
- Reservoir contents would be higher during a drought and when the reservoirs refill if the reservoir is not drained.

Reservoirs

Imposing restrictions would generally have the effect of reserving more water in storage; therefore, storage contents in Denver Water's reservoirs could likely be higher in dry years. Whether storage contents are higher depends on several factors. The amount and location of water reserved in storage would vary depending on the severity and duration of restrictions imposed, on storage conditions in Denver Water's North and South systems, and on hydrologic conditions. Higher water levels would generally have a minor positive impact on recreation as the effects associated with reduced water levels under the Depletion of Strategic Water Supply strategy would be less.

River Segments

Several RFFAs (Table 5-2), which were not included or only partially included in the PACSM, also have the potential to affect the river segments. For the East Slope segments, these projects include the Halligan-Seaman Water Supply Project, the Northern Integrated Supply Project, Rueter-Hess Reservoir, Chatfield Reservoir Storage Reallocation Project, Dry Creek Reservoir, and Augmentation of lower South Platte River Wells, East Cherry Creek Valley Water Project, and the Cache la Poudre Flood Reduction and Ecosystem Restoration Project. As stated in Section 5.3, there is not sufficient information available to model the flow impacts of all of these projects. In most cases, each of these projects is expected to have little or no effect on South Platte River flows. Given the fact that the Moffat Project itself would also have little effect on flows in the lower South Platte River and the low levels of boating and other water-based recreational uses in this segment of the South Platte River, cumulative effects are also expected to be minor.

On the West Slope, most RFFAs that might influence stream flows were already accounted for in the PACSM. An exception to this is a reduction in Xcel Energy's Shoshone Power Plant Call. Although this agreement could influence flows in some portions of the upper Colorado River Basin, the terms of the agreement provide for these potential changes to occur during a period of low recreational use (March 14 to May 20). Any cumulative effects on boating would therefore be minor.

Since storage contents could be higher with restrictions, Denver Water's diversions into storage could be less after a drought and stream flows could increase for a short duration after Denver Water's reservoirs refill. However, this would not occur if a reservoir is drained even with restrictions in place. Conversely, with greater restrictions, during a drought stream flows would be less in some streams as Denver Water would decrease its releases from storage and decrease bypass flows. However, it should be noted that Denver

Water does have the ability to reduce bypass flows during water restrictions. Depending on the level, an increase in stream flow could have either a positive or negative impact on recreation. Increases in stream flow too great may result in a degradation of the fishing experience as high water levels may make it more difficult to catch fish on certain river segments. However, an increase in stream flow may have a positive impact on the boating experience on certain river segments as higher water flows may extend the use season. Conversely, water flows that are too high might make a river unrunable or diminish the experience by covering "play holes."

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4.6.16 Land Use

The affected environment for existing land uses is described for Current Conditions (2006) in Section 3.16. This cumulative impacts analysis evaluates the potential impacts to land use due to each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to land use are evaluated against Current Conditions (2006).

Cumulative impacts to land use would occur if the Moffat Project or another land-based RFFA (refer to Section 4.3.2) conflicts with adopted planning goals or policies, terminates or has a major impact on existing land uses, or results in changes that would interfere with planned land uses in the area. To assess cumulative impacts to existing and planned land uses, parcel ownership data, management and planning documents (including zoning regulations), aerial imagery, and recent development proposals were reviewed.

4.6.16.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Gross Reservoir

Other than direct physical impacts to the Gross Dam and Reservoir footprint, the predominant land-based changes, disturbances, or developments that have occurred or are anticipated to occur are located east of the Front Range foothills, and these would have no measurable cumulative effects to land use near Gross Reservoir. Land uses and management practices are relatively stable in the vicinity of the reservoir and no specific projects or trends could be identified that would result in cumulative land use effects. Overall, cumulative impacts to existing and planned land uses from the Proposed Action with RFFAs are anticipated to be negligible.

River Segments

Facility development would be limited to those items previously discussed, all of which would be located on the East Slope. There would be no facility development in Grand County or other locations on the West Slope, and therefore, the Proposed Action would not result in direct effects on land use at these locations. Project impacts associated with increased stream diversions, which are discussed in Recreation (Sections 4.6.15 and 5.15), Visual Resources (Sections 4.6.17 and 5.17), and other resource sections, would not be of a magnitude that would result in cumulative land use changes on the West Slope.

Future growth and associated development in Grand County, including new water-related infrastructure, is likely to occur within the Fraser River Basin; however the timing of development will depend on a number of economic and other factors. Water rights for existing agriculture, municipal, and other uses would be protected under Colorado water law. Municipal and agricultural diversions per Colorado water law (Colorado Revised Statutes Section 37-92-102[2][b]) would remain responsible for developing a reasonable means of diversion for their water.

Current impacts on irrigation structures and irrigation practices caused by low flow conditions during the late summer and in dry years are partially due to diversions by the existing Moffat Project as well as other upstream diversions, including Windy Gap and Colorado-Big Thompson (C-BT) Project diversions. The proposed Moffat Project would have little to no impact on flows during the late summer and in dry years; therefore, impacts on irrigation structures and practices would not be exacerbated by the proposed Moffat Project with RFFAs. The proposed Moffat Project would not cause additional flow reductions during those times since there would be no *additional* diversions attributable to the Moffat Project in late summer months or in dry years because the Board of Water Commissioners (Denver Water) would have already diverted the maximum amount physically and legally available under their existing water rights without additional storage on line. Appendix Table H-3.1 shows additional diversions through the Moffat Tunnel would occur primarily during the months of May, June, and July in average and wet years. During other months, there would be little to no additional water diverted. Furthermore, Denver Water’s out-of-priority diversions from the Fraser River Basin would be replaced with releases from Williams Fork Reservoir, resulting in no net change in Colorado River flows upstream of these pumps due to out-of-priority Moffat Collection System diversions in dry years.

4.6.16.2 Alternative 1c with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to land use at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (40,700 acre-feet [AF]).

Leyden Gulch Reservoir Site

At the Leyden Gulch Reservoir site, cumulative impacts to land use may occur if planned urban development activities or transportation improvements occur in the general area. Land use in the Leyden Gulch area is currently stable, but the potential for future development is moderate to high. The greatest potential determinant of change in the area would be future industrial/office redevelopment area at the intersection of State Highway (SH) 72 and SH 93 as specified in the City of Arvada Comprehensive Plan (City of Arvada 2005). As noted in the Northwest Arvada Urban Renewal Plan, (2009) the plan is intended to stimulate development of underutilized lands (approximately 2,000 acres) east of SH 93 at SH 72 by creating a commercial and industrial center. The intersection of SHs 72 and 93 is zoned for commercial development by the City of Arvada and several subdivisions are planned in the region. Although the majority of the Project vicinity remains unincorporated, it is highly probable that residential growth would continue westward from Westminster, Arvada, Wheat Ridge, and Golden, with commercial and industrial development along SHs 72 and 93.

Potential improvements to and the realignment of SH 93 would add to these cumulative effects. It is anticipated that construction of these improvements would occur prior to construction of Leyden Gulch Reservoir, thus eliminating any cumulative effects resulting from the construction phase of the projects.

The land use trends previously discussed might be mitigated by planned efforts to protect open space in the reservoir site vicinity. Community and county-wide planning efforts, including the North Plains Community Plan (contributing document to the Jefferson County Comprehensive Master Plan [Jefferson County 2012]) have noted the importance of preserving local viewsheds and acquiring new open space properties west of SH 93. The Leyden Gulch vicinity is identified as a "potential open space preservation area" in this plan.

When combined with the impacts of ongoing urban development or transportation improvements, the land use changes resulting from construction of Leyden Gulch Reservoir under Alternative 1c would result in a cumulatively major modification of existing land use patterns. What is currently a largely undeveloped area would become an area of mixed land use, following a pattern similar to what occurs in many urban fringe settings in the Denver Metropolitan area. In this context, the contribution of Leyden Gulch Reservoir would be a relative minor component of the overall change, but the degree of range would be major.

4.6.16.3 Alternative 8a with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to land use at Gross Reservoir would be similar to those described above for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (52,000 AF).

South Platte River Facilities

The South Platte River Facilities are consistent with existing and planned (zoning) land uses. If future site-specific land- or water-based actions are compatible with the planned land use efforts and zoning requirements, it is assumed there would be minor cumulative effects as a result of the proposed facilities.

Cumulative effects as a result of conduit construction would occur if construction overlapped in location or schedule with other traffic delays or detours. At this time it is impossible to identify what, if any, road segments may be simultaneously impacted during conduit construction.

4.6.16.4 Alternative 10a with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to land use at Gross Reservoir would be the same as those described for Alternative 8a.

Denver Basin Aquifer Facilities

Land use cumulative impacts to City and County of Denver properties as a result of construction and operations of Denver Basin Aquifer Facilities are primarily related to diminished recreational experiences and/or scenic quality; these impacts are reflected under Sections 5.6.13 and 5.6.15. Cumulative effects to recreation and visual quality are expected to be minor since areas surrounding the storage facility locations are for the most part already built-up.

4.6.16.5 Alternative 13a with Reasonably Foreseeable Future Actions

Gross Reservoir

The total environmental effects to land use at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (60,000 AF).

South Platte River Facilities

Agricultural water rights transfer under Alternative 13a would likely occur in Weld County, which is losing agricultural lands at a rapid rate. In the 15-year period between 1987 and 2002, Weld County alone lost 271,491 acres of agricultural land (Environment Colorado Research and Policy Center 2006). In this context, the amount of land that may be affected by the Moffat Project is relatively minor, and some, if not a majority of these lands would likely be converted to nonagricultural uses by ongoing trends towards urbanization. The timing and location of these conversions is unknown and cannot be accurately predicted. Although future agricultural land conversion is speculative, it is likely that the acreage proposed for conversion under Alternative 13a would represent a negligible to minor contribution to the overall trend.

4.6.16.6 No Action Alternative with Reasonably Foreseeable Future Actions

There would be no cumulative environmental impacts to land use as a result of the No Action Alternative since no ground disturbing activities would occur. Overall, cumulative impacts to existing and planned land uses are anticipated to be negligible.

4.6.17 Visual Resources

The affected environment for visual resources is described for Current Conditions (2006) in Section 3.17. This cumulative impacts analysis evaluates the visual resources impacts due to each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to visual resources are evaluated against Current Conditions (2006).

Land-based actions resulting in direct impacts are relevant for East Slope river segments only since no construction activities would occur on the West Slope. Construction or development adjacent to these river segments may obstruct or impair views of the river or the visual or scenic quality from a setting near the river, such as a park or community space. However, past, present, or reasonably foreseeable future land-based actions would not directly impair any river segment's intrinsic scenic attributes such as the occurrence of whitewater, riffles, and still pools or color and clarity. Overall, there would be no cumulative impact to the visual or scenic attributes of the affected East Slope river segments.

4.6.17.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Gross Reservoir

Visual impacts at Gross Reservoir are generally related to the increase in scale of the reservoir and dam. With the exception of the permanent quarry site and the auxiliary spillway, the general character of the landscape would not change, but viewers would have a different perspective due to the larger scale of the water feature and dam in the viewshed. Overall, with time the impacts are considered minor to moderate. Other than direct visual impacts to the Gross Dam and Reservoir footprint, the predominant land-based changes, disturbances, or developments that have occurred or are anticipated to occur are located east of the Front Range foothills, and these would have no measurable cumulative effects to visual resources near Gross Reservoir. Land uses and management practices are relatively stable in the vicinity of the reservoir, and no specific projects or trends could be identified that would result in cumulative visual effects.

River Segments

There is a strong correlation between flow levels and how viewers rate the aesthetic appearance of a given stream. Low flows (primarily in winter and early spring months), when much of the channel is not occupied by water and the stream has a "dried up" appearance, are generally rated lower in aesthetic quality than higher flow conditions. Similarly, peak flow levels are also generally rated lower in aesthetic quality than normal flow levels. For example, a study of the Cheoah River in North Carolina that used visual preference survey techniques found that viewers nearly doubled their preference ratings for each successive flow increase between a low flow of 25 cubic feet per second (cfs) up to

230 cfs. However, as flows increased above 230 cfs, there was a rapid drop in the preference ratings as flows increased to 670, 950 and ultimately 1,130 cfs (EDAW 2002).

The conclusions in the North Carolina study are supported by similar results from other studies. For example, a study on the Cache la Poudre River in Colorado showed that scenic quality ratings increased as flow increased, but only to a certain point. In the Colorado study, this point occurred at approximately 1,300 cfs, or 65 percent (%) of the average flow in June. Scenic quality ratings decreased at flows above 1,300 cfs (Brown and Daniel 1991). Another example involved a study on the Virgin River in Zion National Park, which showed that during periods of low flow, small increases in flow resulted in a dramatic increase in aesthetic quality ratings. However, there was little or no improvement in ratings at medium and high flows (Whittaker and Shelby 2002). As Litton reported (Litton 1984), the lower aesthetic quality ratings may be attributable to the fact that higher flows tend to drown out riffles, pools, and other features of interest within the stream channel.

The Moffat Project with RFFAs would have a varying level of effect on stream flows, diminishing flows at some locations and increasing flows at other locations and at different times of the year. In general, the Moffat Project with RFFAs would have only a minor effect on flow levels during periods of low flows, when streams are most sensitive to visual change. Most of the flow changes would occur during periods of naturally higher flows (May, June, and July). The resulting flows would still be within the range of natural variability, both seasonally and from year to year, that is acceptable to and expected by most viewers, as described in Section 3.17.5. The visual experience in mountain communities often contributes to a diverse recreation experience, and to some extent, helps to characterize surrounding land uses. Given the high amount of visitation in some mountain communities for recreation and tourism, and as retirement destinations, flow reductions in certain times of the year may have minor, indirect effects to the overall experience for visitors and residents. Exceptions to these general statements are addressed in more detail in the following sections, considering Current Conditions (2006) and the Proposed Action combined with RFFAs.

A high degree of variability occurs from year to year under Current Conditions (2006). For example, on the Fraser River below Crooked Creek, high flows in an average year (June) reach 492 cfs compared to 1,051 cfs in a wet year and only 88 cfs in a dry year. In all river segments, the visual change between Current Conditions (2006) and Proposed Action with RFFAs becomes less perceptible downstream as flow reductions are smaller relative to the total stream volume. The high degree of variability that would occur with implementation of a Project alternative would make it difficult for most observers to determine if flow variations are naturally occurring or are attributed to the Moffat Project with RFFAs. As discussed in Section 4.6.8, reduced flows are not anticipated to cause any landscape scale changes in riparian vegetation communities. Therefore, the Moffat Project with RFFAs is not expected to adversely affect the visual quality of any stream corridors through modification of existing vegetation.

The cumulative effects of water-based actions on visual resources, i.e., additional diversions associated with new water projects and increasing demands on the affected river segments (both East Slope and West Slope segments), are incorporated into the direct and indirect impacts discussions that follow.

Colorado River

In average years under the Proposed Action with RFFAs, average monthly flow changes would range from 0% to -35% compared to Current Conditions (2006), with the greatest reductions typically occurring in May. Upstream locations, e.g., Hot Sulphur Springs, would show a greater decrease than locations further downstream. These reductions would fall within the normal range of seasonal and annual variability and would be only minimally detectable to most observers in high flow months. For example, at Hot Sulphur Springs a reduction of average monthly flows in May from 457 to 301 cfs (-34%), which is the highest monthly change, would not fundamentally change the stream's appearance but may still be noticeable to casual observers. However, as noted in studies cited at the beginning of this section, flow reductions during periods of high flow may not be perceived as adverse. Flow reductions are more likely to result in adverse effects during periods of low flows, which at Hot Sulphur Springs would typically be less than 5% during the low flow period from October through the winter. This degree of flow change would result in a minor adverse impact on visual quality.

At lower locations in the basin (e.g., near Kremmling), flow reductions would be less prominent due to the increased volume and capacity of the river. Flow reductions would not be detectable to most observers and impacts would be negligible.

Wet year flow changes, although significant (-44% in April and -33% in May at Hot Sulphur Springs) would still be within the normal range of seasonal and annual variability, and would still be higher than average year flows for these same months. Overall, when comparing Current Conditions (2006) to the Proposed Action with RFFAs, wet year flow reductions would not be apparent to most observers and would not be perceived as adverse.

At all locations between Hot Sulphur Springs and Kremmling, flow changes during dry years, when the river would be most vulnerable to visual change, would be minor, typically increasing or decreasing by less than 5%. This would result in negligible cumulative impacts.

Fraser River

In average years with implementation of the Proposed Action with RFFAs, average monthly flow reductions along the Fraser River main stem at Winter Park would be greatest in June at -49%, and drop to -3% by August compared to Current Conditions (2006). At downstream locations, i.e., below Crooked Creek), the reductions in June and August would be -21% and -12%, respectively. At higher locations in the basin, e.g., Fraser River below Vasquez Creek flow reductions of -45% would occur in June and -28% in August are notable. For example, a reduction of average monthly flows in June from 137 to 76 cfs (-45% change), which would occur below the confluence of Vasquez Creek, would likely be easily detectable. However, as noted in studies cited at the beginning of this section, flow reductions during periods of high flow may not be perceived as adverse. Flow reductions are more likely to result in adverse effects during periods of low flows. On this basis, flow changes in the period August through November, which range from a reduction of 28% to 37%, are more critical and would result in adverse visual or aesthetic impacts to the Fraser River. The intensity of the impact would be greatest near the Winter Park gage and would diminish downstream towards the Granby gage.

Periods of low flows (dry years and winter months) are also sensitive and visual impacts would occur during these periods as well. At the location below the confluence with Vasquez Creek, average monthly flow reductions in a dry year would range from 22% to 42%. This level of change would likely be detectable and result in major adverse cumulative impacts on visual quality.

Williams Fork River

Flow changes between Current Conditions (2006) and the Proposed Action with RFFAs would exhibit a similar pattern to that described on the Fraser River. In the upper basin, the greatest absolute flow changes would occur in June and July. For example, average flows in July under Project with RFFAs implementation would drop from 50 to 30 cfs near the Steelman Creek gage and from 86 to 66 cfs above the Darling gage compared to Current Conditions (2006). As described for other locations, this degree of change is within the normal range of seasonal and annual flow changes and would likely not be apparent to most observers or perceived as adverse. In upper portions of the drainage, low flows would also be reduced. Near the Steelman Creek gage, flows in October and November would be reduced by approximately 40%. Although the actual amount of flow is minor (0.5 cfs), it represents a substantial portion of the flow at that time of the year and the reduction would result in moderate to major cumulative adverse impacts. At lower locations in the basin, flow changes are very minor in average years and actually show an increase below Williams Fork Reservoir.

In dry years, flow changes would primarily occur in upper portions of the basin. The degree of change would be major near the Steelman Creek gage where July average flows would drop from 21 to 4 cfs, and from 7 to 4 cfs in June. This degree of change would be highly apparent to most observers, thus creating major adverse cumulative impacts. A similar degree of change would occur downstream near the Darling gage. At locations further downstream, flow changes would generally be minor throughout the year except for below Williams Fork Reservoir. At this location, flows would substantially increase in most months in normal and dry years. The greatest increase would occur in July of an average year when flows would increase by over 40% compared to Current Conditions (2006), but still remaining below flows in a wet year. This increase would be detectable to most observers but is within the normal range of variability (i.e., similar to flow in normal years), and would not likely be perceived as an adverse cumulative impact.

Blue River

Blue River flows are highly variable between seasons and years because of the dam releases from Dillon and Green Mountain reservoirs. In average years under the Proposed Action with RFFAs, average monthly flow reductions would range from -1% to -27% below the confluence with Boulder Creek between Dillon and Green Mountain reservoirs. Most of the increased diversions would occur during periods of naturally higher flows (May and June). These reductions would fall within the normal range of seasonal and annual variability and would not be detectable to most observers, and would likely not be perceived as adverse. For example, a reduction of average monthly flows in June from 1,043 to 789 cfs (-24%), which would occur below Boulder Creek, would not fundamentally change the stream’s appearance and flows would still be significantly higher than flows at all other times of the year. Flow reductions would also occur during periods of lower flows, ranging from 11% in September to 15% in October. Although a lower percent reduction than in June, these reductions would occur at a time when the river is more sensitive to flow changes and would result in minor cumulative adverse impacts on visual quality.

Overall, reductions occurring at downstream locations (i.e., below Green Mountain Reservoir), would be less detectable than upstream reductions. Flow reductions would be greatest in June, reaching 30%, but the cumulative effects would be minor and similar to those occurring further upstream. However, reductions during periods of lower flows would be less, reaching only 3% to 4% in September and October. This degree of change would result in no cumulative impacts on visual quality.

When comparing Current Conditions (2006) to the Proposed Action with RFFAs below Green Mountain Reservoir, wet year flow reductions occurring from October through March would drop flows to rates comparable to average year flows for the same period. In most cases, wet year flow reductions from the Proposed Action with RFFAs would not cause flows to fall below average year rates. As such, these reductions would fall within the normal range of seasonal variability and would not be detectable to most observers.

South Boulder Creek

South Boulder Creek would serve as the conduit for increased West Slope diversions under the Proposed Action. Above Gross Reservoir, overall flow changes (increases) would be imperceptible to most observers in most months of all years, except in the wettest months, in which flow increases would range from the most at 20% in June, to 19% and 9% in July and May, respectively, in average years. In periods of higher flows (e.g., summer months) in wet years, flow increases may be detectable by some highly skilled observers. When comparing Current Conditions (2006) to the Proposed Action with RFFAs above Gross Reservoir, flow increases in South Boulder Creek would be imperceptible to casual observers with the exception of June when flow increases would be 120 cfs (20%) in average years and 175 cfs (39%) in wet years. Overall, cumulative visual impacts to South Boulder Creek above Gross Reservoir would be minor and not likely to be perceived as adverse.

When comparing Current Conditions (2006) to the Proposed Action with RFFAs immediately below Gross Reservoir, a high degree of change (increase) would occur in the months of October to February of all years as a result of additional West Slope diversions (stored in Gross Reservoir) being released into South Boulder Creek under the Proposed Action. The increase would be most dramatic in January and February of average years, with flow increases of 865% and 835%, respectively. Such increases would result in flow levels more characteristic of early spring (March and April) and would likely be noticeable though not likely to be perceived as adverse. Conversely, during the higher flow period (May to July), the flows would be reduced downstream of Gross Reservoir, with a -20% change in May, -8% in June, and -7% in July, which would not be apparent to most observers. Further downstream, near Eldorado Springs, (Node 57180), there would be no perceptible changes in stream flows under the Proposed Action with RFFAs compared to Current Conditions (2006) in all years.

In general, when comparing Current Conditions (2006) to the Proposed Action with RFFAs, reservoir outflow changes would be significantly higher in winter months (i.e., low flow periods) of all years immediately below Gross Reservoir. Average year flows are projected to increase by as much as 865% below the dam in January. These additions (while high in the winter) are characteristic of early spring flows, and though perceptible, would not create an adverse effect.

North Fork South Platte River

When comparing Current Conditions (2006) to the Proposed Action with RFFAs, the North Fork South Platte River would experience a wide range of flow changes across all months of all years. The average annual flow would increase by approximately 26% below the Geneva Creek gage. During periods of lower flows, these increases would likely be perceived as beneficial. Flow increases during the summer months from May through September would be the most significant, and range from 29% in June to 54% in September and may be noticeable to a casual observer, resulting in runoff-like flow conditions through October. A decrease of winter flows of ranging from -11% to -22% would also occur from November through March. These decreases would result in minor to moderate adverse cumulative impacts to visual quality.

South Platte River

Under the Proposed Action with RFFAs, visual changes resulting from flow changes would vary depending on location. Overall, stream flow changes (both reductions and increases) are expected to be only minimally detectable to most observers and would not adversely affect stream appearances. Below Chatfield Reservoir, flow changes (depletions) would be much more variable, but would remain within the normal range of variability and would therefore, with several exceptions, still be imperceptible to the casual observer. Exceptions would occur in July and August of average years (-22% and -33% reduction, respectively) and in July and August of dry years (-42% and -51% reduction, respectively) when depletions may adversely affect stream appearances. In August, when flows are lower, this level of flow reduction would be noticeable and result in a moderate level of impact on visual quality. Where minor stream flow increases would occur (November-January), the cumulative impacts are expected to be minor and beneficial to visual resources.

When comparing Current Conditions (2006) to the Proposed Action with RFFAs, flow changes on the South Platte River, with the exception of immediately below Chatfield Reservoir, would be imperceptible to the casual observer, in which case no additional impacts are expect to occur to visual resources. Under the Proposed Action with RFFAs, flows on the South Platte River below Chatfield Reservoir (but above Denver gage) would increase by approximately 11% and 10% during the months of December and January in average years, about 26% and 29% during the months of January and April in dry years, and 17% in December of wet years, resulting in a minor beneficial effect on aesthetic quality along this reach. Flow depletions in all other months of all years would be imperceptible to casual observers.

4.6.17.2 Alternative 1c with Reasonably Foreseeable Future Actions

Gross Reservoir

The slightly smaller surface size and lower dam height of Gross Reservoir under this alternative would not substantially change from the cumulative visual impacts described under the Proposed Action with RFFAs.

Leyden Gulch Reservoir Site

At the Leyden Gulch Reservoir site, there would be a major change in the scenic attributes of the landscape, where the existing rolling grassland landscape would be converted into a reservoir, resulting in a permanent contrast from the existing landscape features. Adding a water feature to the landscape may be considered an improvement in the diversity of visual elements, but would fragment the existing scenic character resulting in moderate impacts.

As previously stated, construction of Leyden Gulch Reservoir and associated facilities would create a high degree of contrast with the existing character of the landscape. When combined with the impacts of ongoing or proposed urban development or transportation improvements, the change in visual condition would result in a cumulatively major modification of the context in which this area is viewed. Instead of an existing landscape of relatively intact prairie/rangeland, the man-made reservoir and facilities, and other new developments, would fragment the viewshed and change the overall character of the landscape.

River Segments

Total environmental effects to visual resources under Alternative 1c would be similar to those described for the Proposed Action with RFFAs.

4.6.17.3 Alternative 8a with Reasonably Foreseeable Future Actions

Gross Reservoir

The slightly smaller surface size and lower dam height of Gross Reservoir under this alternative would not substantially change the cumulative visual impacts described under the Proposed Action with RFFAs.

South Platte River Facilities

Past and ongoing mining and industrial uses of the area around the South Platte River Facilities have impacted the natural, scenic attributes of land along the South Platte River. The proposed facilities are compatible with the existing diminished scenic quality and are comparable in scale to the existing structures and buildings. The proposed facilities would not result in additional diminishment of the viewshed. Additionally, future land-based actions are anticipated to be consistent with past and present gravel and industrial uses, including the proposed facilities, due to zoning regulations which stipulate that these uses are compatible with future land use plans.

Overall, construction of the conduits would result in minor cumulative effects when combined with the impacts of past, present, or RFFAs.

The loss of mature vegetation, primarily mature trees, would result in minor cumulative effects to visual resources when combined with the loss of mature vegetation during other adjacent urban or transportation development projects.

River Segments

Total environmental effects to visual resources under Alternative 8a would be similar to those described for the Proposed Action with RFFAs.

4.6.17.4 Alternative 10a with Reasonably Foreseeable Future Actions

Gross Reservoir

The slightly smaller surface size and lower dam height of Gross Reservoir under this alternative would not substantially change from the cumulative visual impacts described under the Proposed Action with RFFAs.

Denver Basin Aquifer Facilities

The well clusters associated with the Denver Basin Aquifer Facilities, and future land- or water-based actions would only result in cumulative impacts if future development directly encroached on park properties or park viewsheds throughout the City and County of Denver. At this point, the impacts of the Denver Metropolitan area development patterns and demands for City or County owned property is speculative, the area is already built-up, and major changes to visual resources in or surrounding the existing parks are not expected.

River Segments

Total environmental effects to visual resources under Alternative 10a would be similar to those described for the Proposed Action with RFFAs.

4.6.17.5 Alternative 13a with Reasonably Foreseeable Future Actions

Gross Reservoir

The slightly smaller surface size and lower dam height of Gross Reservoir under this alternative would not substantially change from the cumulative visual impacts described under the Proposed Action with RFFAs.

South Platte River Facilities

The total environmental effects to visual resources for the South Platte River Facilities are the same as those described above for Alternative 8a. The combined effects of converting irrigated cropland under Alternative 13a to dryland agriculture and population growth and development through agricultural water rights transfers would result in moderate adverse cumulative effects to visual resources in the immediate area of the converted cropland. The exact locations of the transfers are unknown at this time.

River Segments

Total environmental effects to visual resources under Alternative 13a would be similar to those described for the Proposed Action with RFFAs.

4.6.17.6 No Action Alternative with Reasonably Foreseeable Future Actions

As there would be no ground-disturbing activities, there would be no direct impacts to visual resources as a result of the No Action Alternative. With this alternative, the Board of Water Commissioners (Denver Water) would continue to operate their existing system under a higher demand. In addition, the No Action Alternative would result in depletion of the 30,000 acre-feet (AF) Strategic Water Reserve at times and more frequent mandatory restrictions on use during droughts. Therefore, minor indirect impacts to visual resources would occur at Gross Reservoir as a result of more frequent and prolonged drawdowns. The area between the normal water elevation and the minimum drawdown level would remain barren of vegetation and would create unattractive visual contrasts for observers, particularly recreationists. In addition, further diversions would occur as demands increase at many locations on both the East and West slopes. Cumulative impacts on a drainage by drainage basis are discussed in the remainder of this section.

River Segments

Colorado River

Flow modifications and resulting impacts at all locations on the Colorado River would be very similar to those described for the Proposed Action with RFFAs.

Fraser River

Impacts at all locations on the Fraser River would be similar to those described for the Proposed Action with RFFAs, but at a lower level of intensity. Flow reductions would be lower than those associated with the Proposed Action with RFFAs, generally 10% to 30% less during the period May through August. As a result, the degree of change would be less and impacts to visual quality would be negligible to minor. However, a similar level of flow reductions would occur during periods of lower flows (August through the winter), and the resulting impacts would be very similar to those described for the Proposed Action with RFFAs.

Williams Fork River

With one exception, impacts at all locations on the Williams Fork would be similar to those described for the Proposed Action with RFFAs. Flow reductions would generally be within 5% to 10% of the reductions associated with the Proposed Action with RFFAs, resulting in a minor decrease in impact intensity. The one exception is the upper portion of the drainage, where flow reductions would be considerably less. For example, at the Williams Fork River below Steelman Creek gage average flows in June would be 4% less than Current Conditions compared to 21% for the Proposed Action with RFFAs.

Blue River

Flow reductions would be very similar between the No Action Alternative and the Proposed Action, resulting in impacts very similar to those described for the Proposed Action with

RFFAs. Flow reductions resulting from the No Action Alternative are generally slightly higher but within about 5% of those resulting from the Proposed Action with RFFAs.

South Boulder Creek

In average years, flow reductions resulting from the No Action Alternative would be similar to those resulting from the Proposed Action with RFFAs, particularly in the segment below Gross Reservoir. Above Gross Reservoir, flow increases in June and July would be reduced by approximately 10% compared to the Proposed Action with RFFAs, but impacts would remain similar. Flow increases in wet years would be approximately 25% less in June under No Action, but impacts would remain similar to those described for the Proposed Action with RFFAs. At other times of the year, flow changes in wet years would be similar for both alternatives. This would also be true during dry year conditions.

North Fork South Platte River

Flow reductions would be very similar under both the No Action Alternative and the Proposed Action with RFFAs, resulting in similar impacts to those previously described for the Proposed Action.

South Platte River

Impacts at all locations would be very similar to those described for the Proposed Action with RFFAs.

4.6.18 Cultural/Historical/Paleontological Resources

The affected environment for cultural and paleontological resources is described for Current Conditions (2006) in Section 3.18. This cumulative impacts analysis evaluates the potential effect of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to cultural and paleontological resources are evaluated against Current Conditions (2006).

The Moffat Project with RFFAs would involve ground-disturbing activities in the Front Range that could impact cultural resources through direct impacts to prehistoric or historic sites or fossil localities, or also by impacting the setting or context of cultural or historical properties. Many of the past, present, and future ground-disturbing activities have occurred, or will occur, on private land where cultural, historical or paleontological resource impact assessment and mitigation may not be required. This can result in an irretrievable loss of resources. Those projects that are subject to Federal, State, or local government cultural, historical, or paleontological resource requirements can be assessed and mitigated, but would add to the incremental cumulative effect to resources in the region.

4.6.18.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Past regional population growth and development in the Front Range has mostly occurred east of the foothills, but has had some effect on the Gross Reservoir area. In addition to areas around the existing Gross Reservoir, the principal developments that have occurred are large-acre residential areas, roads, and a railroad. Impacts from the Moffat Project with RFFAs to cultural, historical, or paleontological resources at Gross Reservoir would be minor, as areas of proposed ground disturbance would be surveyed for cultural, historical, or paleontological resources and impacts would be mitigated. This would result in minor cumulative impacts to cultural resources.

The cumulative effects to cultural, historical, or paleontological resources may also be beneficial to some degree, since many of the reasonably foreseeable future projects would require cultural, historical, or paleontological resource surveys that can result in valuable data being collected that otherwise would not be collected until sometime in the future, if at all. For instance, at the Rueter-Hess Reservoir Project, located in Douglas County, Colorado, pre-construction surveys for cultural resources resulted in the discovery of many pre-historic artifacts, which were then recorded and preserved for future study and reference.

4.6.18.2 Alternative 1c with Reasonably Foreseeable Future Actions

The total environmental effects to cultural, historical, or paleontological resources at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (40,700 acre-feet [AF]).

The Leyden Gulch Reservoir site is within the expected growth corridor of the northwest Denver Metropolitan area related to transportation improvements and urban development in Jefferson County. Impacts from the Moffat Project with RFFAs to cultural, historical, or paleontological resources at the proposed Leyden Gulch Reservoir site would be minor, as areas of proposed ground disturbance would be surveyed for cultural, historical, or paleontological resources and impacts would be mitigated. This would result in minor cumulative impacts to cultural resources.

The total effect to cultural, historical, or paleontological resources may also be beneficial to some degree, since many of the reasonably foreseeable projects would require cultural, historical, or paleontological resource surveys that can result in valuable data being collected that otherwise would not be collected until sometime in the future, if at all.

4.6.18.3 Alternative 8a with Reasonably Foreseeable Future Actions

The total environmental effects to cultural, historical, or paleontological resources at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (52,000 AF).

Impacts from the Moffat Project with RFFAs to cultural, historical, or paleontological resources at the proposed South Platte River Facilities, and along Conduit O would be minor due to the existing disturbed conditions in the area. Areas of proposed ground disturbance would be surveyed for cultural, historical, or paleontological resources and impacts would be mitigated. This would result in minor cumulative impacts to cultural resources.

The total effect to cultural, historical, or paleontological resources may also be beneficial to some degree, since many of the reasonably foreseeable projects would require cultural, historical, or paleontological resource surveys that can result in valuable data being collected that otherwise would not be collected until sometime in the future, if at all.

4.6.18.4 Alternative 10a with Reasonably Foreseeable Future Actions

The total environmental effects to cultural, historical, or paleontological resources at Gross Reservoir would be the same as those described for Alternative 8a.

Impacts from the Moffat Project with RFFAs to cultural, historical, or paleontological resources at the proposed Denver Basin Aquifer Facilities, and along Conduit M would be minor, as areas of proposed ground disturbance would be surveyed for cultural, historical, or paleontological resources and impacts would be mitigated. This would result in minor cumulative impacts to cultural resources.

The total effect to cultural, historical, or paleontological resources may also be beneficial to some degree, since many of the reasonably foreseeable projects would require cultural, historical, or paleontological resource surveys that can result in valuable data being collected that otherwise would not be collected until sometime in the future, if at all.

4.6.18.5 Alternative 13a with Reasonably Foreseeable Future Actions

The total environmental effects to cultural, historical, or paleontological resources at Gross Reservoir would be similar to those described for the Proposed Action with RFFAs, but less ground-disturbing activity would be necessary for the smaller expansion (60,000 AF).

The total environmental effects to cultural, historical, or paleontological for the South Platte River Facilities are the same as those described above for Alternative 8a.

4.6.18.6 No Action Alternative with Reasonably Foreseeable Future Actions

There are no ground-disturbing activities associated with the No Action Alternative; thus, no cumulative impacts to cultural, historical, or paleontological resources are anticipated.

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4.6.19 Socioeconomics

The affected environment for socioeconomics is described for Current Conditions (2006) in Section 3.19. This cumulative impacts analysis evaluates the potential effects on socioeconomics of each Moffat Collection System Project (Moffat Project or Project) alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use with a Project Alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects to socioeconomics are evaluated by comparing to Current Conditions (2006).

This cumulative socioeconomic impact analysis is based on a recognition of the current demographic and economic conditions within the Primary Impact Areas (PIAs) and Secondary Impact Areas (SIAs), as described in Section 3.19. Inputs into the analysis of total socioeconomic impacts include changes in surface water flows, water quality, recreation, land use, visual resources, and transportation activity as a result of each action. Total socioeconomic effects for the PIAs and SIAs address changes to economic and demographic conditions; fiscal conditions; and public facilities and services.

Socioeconomic characteristics potentially affected by land- or water-based activities in the Project area include:

- Employment and business activity;
- Population, age distribution, ethnicity, migration or commuting patterns;
- Housing units, vacancy rates, and home values;
- Operating revenues, expenditures and capital outlays of public entities; and
- Public facilities and services, including police and fire departments; health services; libraries; solid waste disposal; education; water providers and wastewater treatment facilities.

4.6.19.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

4.6.19.1.1 Economic, Demographic and Housing Conditions

Gross Reservoir PIA

The Gross Reservoir PIA includes a small number of year-round and seasonal single-family homes. Although no subdivisions or other major developments are currently planned within the PIA, development of a limited number of large-lot single family homes is expected to occur on private lands within the PIA through 2032. This type of growth is consistent with historical trends for the area; the Proposed Action with RFFAs would neither enhance nor deter growth in the PIA. No commercial development is anticipated for the area and, other than temporary construction jobs, no additional employment would be created in the PIA.

As described in Section 5.19, the Proposed Action with RFFAs would not have any long-term economic or demographic effects within the PIA. Short-term, temporary, construction-related impacts are described in detail in Section 5.19.1, and generally include increased truck traffic and changes to access and recreational opportunities at Gross Reservoir. As a result, a small number of homes along Gross Dam Road may experience minor to moderate short-term impacts to property values. The RFFAs are not anticipated to impact water supplies to homes or businesses in the PIA nor impact the economic or demographic characteristics in the PIA. Overall, total effects to the Gross Reservoir PIA would be negligible.

Boulder County and Denver Metropolitan Area

Population increases are projected to occur in cities, towns, and rural areas within the Denver Metropolitan area and in other areas along the Front Range. The Boulder County population is estimated to increase by about 25 percent (%) by 2030 and the Denver Metropolitan area by about 32% (DOLA 2001-2008). Residential, commercial, and other urban development, as well as development of associated infrastructure, is expected to occur to support anticipated population growth. Population growth will result in other demographic changes in the region, affecting characteristics such as the racial makeup of the population, age distribution or home availability and price.

The Proposed Action is one of the many actions planned to meet the demands of future growth. The collection of reasonably foreseeable water-based projects would create temporary jobs in construction activities and permanent jobs as part of operations and maintenance activities. Additionally, the developed water supplies would meet demands of existing and new customers along the Front Range; supporting economic activity and contributing to the quality of life for residents. In combination with anticipated development and other water-based projects and actions, the Proposed Action with RFFAs would result in temporary, positive, cumulative economic stimulus through job creation and Project-related expenditures.

Short-term temporary increases in income levels would be experienced by the small portion of the population directly employed during the construction phases of various projects. None of the land- or water-based RFFAs are expected to permanently change personal income levels, including household or per capita incomes.

Grand County

Growth in Grand County is most likely to occur within the Fraser River Basin. Population growth and associated development will likely result in employment and other economic opportunities as services are expanded to meet the needs of new county residents; however, the timing of development will depend on a number of economic and other factors. Demographic changes, including racial makeup and age distribution of the population, may occur in the future as the Grand County population grows over time.

None of the West Slope water-based RFFAs would include any construction activities in Grand County or support any other types of economic stimulus to the Grand County economy.

Cumulative changes in Grand County river and stream flows resulting from the water-based RFFAs are discussed in detail in Section 4.6.1 and in Appendix H. Flow reductions would result in water shortages for almost all Grand County water providers, ranging from 1 acre-feet (AF) to 364 AF/yr, as shown in Table 4.3.1-3 and discussed in detail in Section 4.6.19.1.3. These water providers would likely make infrastructure investments and operational changes to reduce or mitigate shortages; therefore municipal water shortages would not likely hinder growth or development in Grand County. The financial impacts of making such investments are discussed in Section 4.6.19.1.2.

As described in Section 3.19, the Grand County economy is heavily dependent on tourism and recreation, including water-based activities such as fishing, boating and skiing and land-based activities, such as hiking and mountain biking. From a Grand County tourism and recreation standpoint, the most impactful aspect of the Full Use with a Project Alternative (2032) scenario will be the anticipated growth on Colorado's Front Range. As population and economic activity grows there, more people will visit Grand County, causing the tourism component of the economy to expand. Total socioeconomic impacts to the Grand County tourist and recreation economy are expected to be negligible to minor based on the following information:

Boating

- Under Full Use with a Project Alternative with RFFAs (2032), total changes in Fraser River flows would reduce the number of days with optimal flows for boating (400 to 900 cfs) by an average of 5 days per year, or about 20%, given average hydrologic conditions (refer to Section 4.6.15).[5] Impacts to boating in wet years would be minor, due to a reduction in the number of days at the highest flow levels. Boating use in this area is low and no commercial use occurs on the Fraser River; many of the private boaters on the Fraser River are local residents. The low use of this river suggests that the cumulative socioeconomic impacts related to boating would be minor; the small number of boaters potentially affected by reduced flows in the Fraser River would not measurably affect the Grand County economy. Impacts to businesses catering to boaters would be negligible.
- The Colorado River is heavily used for a variety of types of boating, including kayaking and commercial rafting. Total impacts to the Colorado River would include diminished average monthly flows between May and September; however, the number of days when flows would fall within the desirable range for boating (800 to 1,250 cfs) would increase by an average of 2 in an average hydrologic year (from about 85 to about 87 days per year).[6] This increase may provide a negligible benefit to local economic activity, in terms of retail sales, especially if additional boaters travel to the area from outside the county, as visitors tend to spend more money relative to locals. Overall, additional boaters and associated economic benefits are likely.

[5]As discussed in Section 4.6.15 Recreation, flow conditions on the Fraser River vary widely from year to year. For example, during the historical period used for PACSM, the number of days in the optimal flow range for boating ranged from zero up to 41.

[6]As discussed in Section 4.6.15 Recreation, flow conditions on the Colorado River vary widely from year to year. The number of days with flows optimal for boating under Full Use with a Project Alternative with RFFAs (2032) would also vary and could even decrease in certain years.

- Downstream of Green Mountain Reservoir, the Blue River provides boating opportunities for private boaters when water levels permit.[7] No commercial boating occurs on this stretch of the Blue River. Under Full Use with a Project Alternative with RFFAs (2032), flow changes would result in an average loss of 7 boating days per year on the Blue River downstream of the reservoir; the average number of optimal days for kayaking would drop from 44 to 37 and those for rafting would decrease from an average of 35 to 28. Changes in Blue River flows would not be expected to measurably impact the local economy, including retailers or service providers catering to boaters. Overall, more boaters and associated economic benefits are likely due to more Front Range visitors.

Fishing

- Aquatic resources, including fish, in the upper Fraser River, several Fraser River tributaries and several tributaries of the Williams Fork River would experience cumulative impacts ranging from moderate beneficial effects to moderate adverse effects, depending on location, with the majority of streams experiencing minor adverse impacts (refer to Section 4.6.11).[8] However, the overall effects on the fishing experience in these areas are expected to be negligible to minor and in several specific areas increased habitat availability could provide an improved fishing experience. There would be no impact to fish or the fishing experience in the Williams Fork (mainstem), Colorado, or Blue rivers. Aquatic habitat and aquatic life in Grand County would be largely unaffected and it is expected that the overall fishing based economy would also be unaffected. Overall, more fishing-based economic activity is likely.

Visual Resources

- Many of the land-based outdoor activities popular in Grand County, such as hiking or nature viewing, are dependent on the surrounding scenery and natural characteristics of the area, including rivers. Total flow reductions along the mainstem of the Fraser River would result in adverse visual impacts in May, June, and July of average and wet years, as described in Section 4.6.17. Moderate adverse effects would occur in the upper reaches of the Fraser River, while downstream of Crooked Creek visual impacts would be negligible to minor and detectable only to skilled observers. During dry years, cumulative flow reductions would result in moderate adverse impacts to the river’s appearance at locations below the confluence with Vasquez Creek. Although the Fraser River is an important part of the character of Grand County, touristic activity is diverse and physically widespread. It is unlikely that tourism or land-based recreational activity would be hampered by these flow reductions given the focal points of tourist or recreation activities and the limited places and instances in which Fraser River flows would be noticeable. Hence, the cumulative socioeconomic effects of these visual impacts would be negligible to minor.

  Visual impacts on the Colorado River would be limited to the Hot Sulphur Springs area, where flow reductions would be only minimally detectable to observers in high flow

[7]As described in Sections 3.15 and 4.6.15 Recreation, the length of the boating season on this stretch of the Blue River varies annually. During the historic period for PACSM, the number of optimal days was as high as 58 in one year; in 2005, the season was only 15 days long.

[8]Affected Fraser River tributaries include Cooper, Little Vasquez, Vasquez, St. Louis, Main Ranch and North Fork Ranch creeks.

months of average years; in June, flow reductions would have negligible to minor impacts on stream appearance. Flow reductions would not be detectable to observers at other locations. Overall, there would be no visual cumulative impacts on the Colorado River.

Other Tourist Destinations

- Several resort developments in Grand County, including the Devil's Thumb Ranch, Winter Park Resort, and Elk Trout Lodge, are located along the Fraser and Colorado rivers. Many of these resorts rely on the existence and aesthetic value of the Fraser or Colorado rivers as a way to market the "experience" of visiting the resort and Grand County (i.e., as a getaway or a place for recreational adventure). Water-based recreational opportunities generally include fishing on rivers or tributaries, rafting or kayaking, and skiing; land-based activities are also offered and may highlight the rivers as a component of the experience. These resorts generally offer other amenities and attractions, such as spa services and dining, that may interest and attract visitors. Given the conclusions of other resources (Recreation, Aquatic Resources, and Visual Resources) and knowledge of the local economy, it is unlikely that sales at these resorts would be measurably diminished as a result of the combination of the Proposed Action and water-based RFFAs.

Based on this information, total flow changes resulting from the combined impacts of the Proposed Action and the water-based RFFAs are unlikely to have a measurable effect on the Grand County's tourism and recreation based businesses or the overall economy. That economy will grow with Colorado's population.

Housing prices in Grand County will be influenced by a number of factors as build-out is approached, including a variety of economic factors affecting real estate transactions, as well as the availability of properties and the demand for primary residences and second homes. The Grand Lake area is an attractive place to live for many of Grand County's year round residents and seasonal homeowners due to the aesthetics of the area and the available recreational opportunities. Property values in this area are linked, in part, to the features and characteristics of Grand Lake, including the lake's water quality and clarity. Studies indicate that reductions in water clarity negatively affect values of lakeside properties in which some portion of the property is directly located at the water's edge (Michael et al. 1996; Krysel et al. 2003). Detailed information about the changes in Grand Lake's water clarity, as indicated by the Secchi disk depth, under Current Conditions (2006), Full Use of the Existing System, and Full Use with a Project Alternative (2032) scenarios, are provided in Section 4.6.2. Visibility is reduced by about half a meter under both the Full Use of the Existing System and Full Use with a Project Alternative (2032) scenarios, as compared with Current Conditions (2006). Assuming that a one meter decrease in water clarity amounts to about a $106 reduction in property value of per foot of lakefront property, the half meter reduction in clarity in Grand Lake would mean a total reduction of about $1.1 million in value for the over 150 parcels directly surrounding Grand Lake.[9] The estimated loss is

[9]Assuming a shoreline of approximately 4 miles (Grand County Public Access Maps), http://co.grand.co.us/GIS/pam_disclaimer.html, accessed June 2012.

equivalent to less than two-tenths of a percent of the total assessed value of all properties in Grand County.[10]

4.6.19.1.2 Fiscal Conditions

Operating Revenues

Land- and water-based RFFAs would generate construction activity along the Front Range and on the West Slope. Construction spending on materials and supplies, as well as spending of wages by construction workers and induced spending by other businesses and employees, would generate sales tax revenue for a number of municipalities and other public entities. The operational phases of the water-based RFFAs would also provide additional tax revenues, depending on the need for maintenance and supplies and the number of new people employed. Given the wide ranging geographical locations of these projects, sales tax revenue generated at any one location may be minimal. Land-based actions, particularly population growth and development, would also result in additional property tax revenue as land is developed for homes and commercial businesses. The location and timing of population growth would depend on a number of factors, including job growth, available land and economic conditions.

Some public entities may be exempt from paying property taxes; in those cases, any land purchased for Project purposes would be permanently removed from property tax rolls. In many instances, public entities receive payment in lieu of taxes as compensation for this loss.

Operating Expenditures and Capital Outlays

The proponents of each reasonably foreseeable water-based project would be responsible for the costs of permitting and constructing Project facilities. These potentially large capital outlays could be paid for via a number of mechanisms, including increased water rates, tap fees or other special charges applied to customers. These entities would also be responsible for on-going operational costs. Besides water utilities, other public agencies would be unlikely to experience increased operational costs or face additional capital investment as a result of water-based RFFAs. However, the exception might be certain downstream Grand County water providers or wastewater treatment providers faced with substantial reductions in flow or water quality issues. Water and wastewater treatment providers are discussed in more detail in Section 4.6.19.1.3.

Public entities may experience increases in operational costs or the need for additional capital investment as the population increases and development occurs along the Front Range and on the West Slope. Impacts to public services, such as emergency responders, are discussed in Section 4.6.19.1.3.

[10]Grand County Abstract of Assessment and Tax Levies, 2011, Grand County Assessor's Office, http://co.grand.co.us/Assessor/Assessor.html, accessed June 2012.

4.6.19.1.3 Public Facilities and Services

Gross Reservoir PIA, Denver Metropolitan Area and Grand County- Police, Fire, Medical, Educational and Library Services

Land-based RFFAs, such as population growth and development, would necessitate the expansion of public services, including police, fire, medical, educational and library services, to meet the demands of additional residents in the Gross Reservoir PIA, Denver Metropolitan area, including Boulder County, and in Grand County.

The Gross Reservoir PIA may also see small slight increases in the demand for emergency services during the construction phase of the Moffat Project as described in Section 5.19.1.6. However, no other water-based RFFAs would occur within the PIA; therefore total short- and long-term effects to services in the PIA would be the same as those described for the Proposed Action with RFFAs in Section 5.19.1.

Each of the future RFFAs has the potential to impact the operating budgets of publicly provided services under the following circumstances:

- Property may be purchased by a public entity that is not subject to property taxes, reducing overall property tax revenues and therefore, revenues of services partially or fully funded through property tax funds;
- Construction phases may require temporary increases in specific services due to Project specific activities. This might include additional sporadic demands for law enforcement, fire departments or medical services due to certain construction activities.

Boulder County and Denver Metropolitan Area Water Providers

As described in Section 3.19, the water rights portfolios and facilities of Denver Metropolitan area and Boulder County water providers are currently adequate to meet customer demands. The East Slope and West Slope water-based projects described in Section 4.3 are in various stages of planning with the purpose of meeting the future demands of Boulder County and Denver Metropolitan area residents.

Grand County Water Providers

The population of Grand County is expected to increase in the future, with growth most likely to occur in the Fraser River Basin. The upper Colorado River Basin Study provides information about current and build-out water demands for Grand County water providers. A comparison of current demands and available supplies indicates that all Grand County water providers are able to meet existing demands. However, Grand County’s water demands are anticipated to increase in the future; build-out municipal and industrial water demands are anticipated to be about 16,168 AF in Grand County compared with about 3,123 AF under Current Conditions (2006). Table 4.3.1-3 provides information about the existing and build-out water demands for each Grand County water provider. Build-out is very unlikely to occur by the year 2032.

West Slope water-based RFFAs, including population growth, would change flow levels in certain portions of various streams and rivers, as discussed in detail in Section 4.6.1 and in Appendix H. The reduction in flows resulting from these projects would cause water shortages for most Grand County water providers in the future. Average shortages under Full Use of the Existing System would range from about 1 AF/yr up to about 358 AF/yr depending on the provider; Table 4.6.1-4 shows the average annual shortages for water providers in the Fraser River Basin.[11] Minimum and maximum annual shortages for each water provider are presented in Appendix H-1.[12] Average annual shortages include bypass reductions in the Fraser River Basin; without bypass reductions, shortages would average between 1 AF/yr and 318 AF/yr depending on the provider (see Table 4.6.1-4). Shortages for Grand County Water and Sanitation District, Winter Park West Water and Sanitation District and the Town of Fraser would decrease by 40 AF, 10 AF, and 42 AF, respectively, without bypass reductions. Shortages faced by the remaining providers would not change as a result of avoided bypass requirements.

The Proposed Action with RFFAs would further reduce flows in the Fraser and Colorado rivers. Under Full Use with a Project Alternative with RFFAs (2032), water shortages are anticipated to range from 1 AF/yr to 364 AF/yr as described in Table 4.3.1-3. Grand County Water and Sanitation District (364 AF/yr) and the Town of Fraser (247 AF/yr) would experience the largest shortages; water shortages for other providers would be 70 AF/yr or less, accounting for about 4.5% or less of total build-out demands for each water provider. Grand County Water and Sanitation District staff indicates they would avoid potential future shortages through infrastructure investments, possibly including a new diversion from the Fraser River mainstem to enable use of their conditional Fraser River water rights, a pump station and Water Treatment Plant (WTP) (refer to Sections 4.6.1 and 5.1). Other Grand County water providers facing shortages would eventually have to acquire additional water rights or find other solutions to close the gaps between available supplies and demands. These actions would likely require some amount of capital investment on the part of water providers, potentially resulting in rate and/ or fee increases for customers.

Changes in water quality resulting from the combination of future actions is discussed in Section 4.6.2. Water quality changes may be due to the percentage of treated wastewater in rivers or to increased water temperatures during periods of lower flows or increased wastewater discharge. If water providers are required to undertake additional treatment activities or otherwise upgrade treatment facilities in order to meet drinking water standards, it is likely that water rates would increase.

None of the East Slope water-based actions would affect water supplies of Grand County water providers.

Boulder County and Denver Metropolitan Area Wastewater Treatment

Denver Metropolitan area and Boulder County wastewater treatment facilities are currently able to provide adequate service to customers and meet existing demand. A formal analysis comparing Current Conditions (2006) to conditions under Full Use with a Project Alternative with RFFAs (2032) for these wastewater treatment providers was not conducted since the flow changes modeled in Platte and Colorado Simulation Model (PACSM) for

[11] The Columbine Lake Water District and the Town of Grand Lake are not located within the Fraser River Basin. The Columbine Lake Water District would not experience any shortages under Full Use with a Project (2032); the Town of Grand Lake would experience 1 AF of annual shortage.

[12] The timing and exact amount of future shortages would depend on the economic circumstances affecting future development.

relevant rivers and streams are estimated to be minimal, generally increasing or decreasing by less than 10% in some months and not changing at all in other months. Increases in river flows would have no impact on the ability of wastewater treatment facilities to discharge effluent in compliance with water quality standards, and the small flow reductions in specific river stretches would also not likely impact these providers.

Grand County Wastewater Treatment

Wastewater Treatment Plants (WWTPs) located in Grand County that discharge treated wastewater into the Fraser River watershed are listed in Section 3.2.5.1. Wastewater treatment providers must meet National Pollutant Discharge Elimination System (NPDES) permit requirements for wastewater treatment and discharge based on acute and chronic low flows. According to the PACSM results, current Fraser River flow conditions are adequate to support the effluent discharged from relevant Grand County treatment plants except in the stretch of river below St. Louis Creek during August and September and in the stretch of river below Vasquez Creek in September. Flows in those particular stretches of the Fraser River are not currently high enough to meet summertime 30-day low flow requirements in the months indicated.

The combination of future land- and water-based RFFAs would change flows in certain portions of various streams and rivers as described in detail in Section 4.6.1 and in Appendix H. Population growth and development in Grand County, and associated increases in water demands and wastewater discharges, are expected to have the greatest impact on stream flow and water quality, contributing to total environmental effects, especially during periods of lower flows. Population related impacts to flows will be the direct result of Grand County water providers drawing more water from the Fraser River and tributaries to meet the demands of additional residential and commercial customers. Lower flows could result in tighter standards for NPDES permits; however, permit standards may become tighter for these operators prior to the full effects of population growth due to regulations affecting WWTPs, specifically, the Nutrient Management Control Regulation passed by the Colorado Department of Public Health and Environment (CDPHE), effective as of September 30, 2012.[13]

The Winter Park and Fraser WWTPs are the most likely to be affected by changes in flows between Current Conditions (2006) and conditions under Full Use with a Project Alternative with RFFAs (2032). These plants would experience decreases in low flows under the Full Use of the Existing System scenario; however, the 2032 scenario would not result in any additional changes in flows for these plants. As a result of changes in flows, the Fraser WWTP may be required to upgrade to a tertiary treatment process or make other infrastructure changes; this would involve a substantial capital investment on the part of the sanitation districts that use the plant, which would likely impact the local mill levy, as well as rates for customers. Grand County Water and Sanitation District's long range plans potentially include a new wastewater peaking plant, estimated to cost between $4 and $5 million. Other Grand County wastewater providers may also be required to upgrade, expand or construct new facilities to meet discharge permit requirements as a result of the combination of reasonably foreseeable future water-based actions, including the recently

[13]Colorado Department of Public Health and Environment, Water Quality Control Division, Regulation #85.

passed nutrient regulations. These activities would require capital investments, likely resulting in increases in customer rates.

None of the future East Slope water-based actions would appear to affect wastewater treatment operations in Grand County.

Table 4.6.19-1 briefly summarizes the total effects experienced by the Gross Reservoir PIA and affected counties.

Table 4.6.19-1
Summary of Total Socioeconomic Impacts
for the Proposed Action with RFFAs (2032)

	Gross Reservoir PIA	Boulder County and Denver Metropolitan Area	Grand County
Economic Conditions	Negligible, positive	Negligible, positive	Negligible, positive and negative
Demographic Conditions	Negligible increase in population	Population growth is anticipated	Population growth is anticipated
Housing Conditions	Temporary minor to moderate impact to salability	Housing availability and price linked to population growth	Housing availability and price linked to population growth
Fiscal Conditions	Negligible	Negligible	Negligible
Water Providers	Negligible	Benefits and costs for many providers as they develop projects to meet demands	Benefits and costs for many providers as they develop projects to meet demands
Wastewater Treatment Plants	Not applicable	Potential upgrades necessary	Potential upgrades necessary
Other Public Facilities and Services	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth

Source: Harvey Economics, 2012.

4.6.19.2 Alternative 1c with Reasonably Foreseeable Future Actions

4.6.19.2.1 Economic, Demographic and Housing Conditions

Gross Reservoir PIA

Total economic and demographic effects within the Gross Reservoir PIA would be similar to those described for the Proposed Action with RFFAs.

Leyden Gulch PIA

The PIA for the Leyden Gulch Reservoir site is likely to experience residential and commercial growth in the future, although Jefferson County and the City of Arvada plan on maintaining open space in the area of the proposed Leyden Gulch Reservoir. Construction would create a number of temporary jobs and would create a permanent open space once construction was complete. This would add to the positive socioeconomic impacts created by other future land-based actions by providing additional, temporary, stimulus to the economy and enhancing county and local plans for the area.

Other than the Moffat Project, none of the reasonably foreseeable water-based projects would occur within the Leyden Gulch PIA and most of the projects are located far enough away that residents and businesses in the PIA would not experience increased employment or retail activity. None of the water-based RFFAs would permanently impact demographic or economic conditions in the Leyden Gulch PIA. Although some water providers in the PIA would benefit from development of water supplies as part of the Moffat Project, none would benefit from other water-based RFFAs. Therefore, total demographic and economic effects on the PIA resulting from water-based RFFAs would be the same as those described in Section 5.19.2.

Denver Metropolitan Area and Boulder and Jefferson Counties

Total economic and demographic effects within the Denver Metropolitan area and Boulder County would be similar to those described for Proposed Action with RFFAs. In addition to the enlargement of Gross Reservoir, the development of Leyden Gulch Reservoir would create additional jobs, resulting in a slightly larger, positive, cumulative economic impact in Jefferson County.

Grand County

Total economic and demographic effects in Grand County under Alternative 1c would be the same as described for the Proposed Action with RFFAs, except that the total reduction in property value of parcels surrounding Grand Lake would amount to $1.34 million, compared with $1.1 million under the Proposed Action with RFFAs.

4.6.19.2.2 Fiscal Conditions

Impacts to operating revenues, operating expenditures and capital outlay expenditures for public agencies would be similar to those described for the Proposed Action with RFFAs.

4.6.19.2.3 Public Facilities and Services

Total impacts to public facilities and services in the Gross Reservoir PIA, Boulder County, Denver Metropolitan area and Grand County, including police departments, fire departments, medical facilities, educational facilities, libraries, water providers, and wastewater treatment facilities would be similar to those described for the Proposed Action with RFFAs. The general types of impacts applicable to services in those areas would also apply to the Leyden Gulch PIA and to Jefferson County.

Table 4.6.19-2 briefly summarizes the total effects experienced by the Gross Reservoir PIA and affected counties.

Table 4.6.19-2
Summary of Total Socioeconomic Impacts for Alternative 1c with RFFAs (2032)

	Gross Reservoir PIA	Leyden Gulch PIA	Boulder and Jefferson Counties, and Denver Metropolitan Area	Grand County
Economic Conditions	Negligible, positive	Negligible, positive	Negligible, positive	Negligible, positive and negative
Demographic Conditions	Negligible increase in population	Limited population growth is anticipated	Population growth is anticipated	Population growth is anticipated
Housing Conditions	Temporary minor to moderate impact to sales price	Limited increase in housing units	Housing availability and price linked to population growth	Housing availability and price linked to population growth
Fiscal Conditions	Negligible	Negligible	Negligible	Negligible
Water Providers	Negligible	Negligible	Benefits and costs for many providers as they develop projects to meet demands	Benefits and costs for many providers as they develop projects to meet demands
Wastewater Treatment Plants	Not applicable	Not applicable	Potential upgrades necessary	Potential upgrades necessary
Other Public Facilities and Services	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth

Source: Harvey Economics, 2012.

4.6.19.3 Alternative 8a with Reasonably Foreseeable Future Actions

4.6.19.3.1 Economic and Demographic Conditions

Gross Reservoir PIA

Total economic and demographic effects within the Gross Reservoir PIA would be similar to those described for the Proposed Action with RFFAs.

Denver Metropolitan Area and Boulder and Adams Counties

Total economic and demographic effects within the Denver Metropolitan area and Boulder County would be similar to those described for the Proposed Action with RFFAs. In addition to the enlargement of Gross Reservoir, the development of the South Platte River Facilities, Advanced Water Treatment Plant (AWTP) and conduits would create a larger number of jobs and have a slightly larger, positive, cumulative economic impacts in Adams County.

Grand County

Total economic and demographic effects in Grand County would be the same as described for the Proposed Action with RFFAs, except that the total reduction in property value of parcels surrounding Grand Lake would amount to $1.34 million, compared with $1.1 million under the Proposed Action.

4.6.19.3.2 Fiscal Conditions

Impacts to operating revenues, operating expenditures and capital outlay expenditures for public agencies would be similar to those described for the Proposed Action with RFFAs.

4.6.19.3.3 Public Facilities and Services

Total impacts to public facilities and services in the Gross Reservoir PIA, Boulder County, Denver Metropolitan area and Grand County, including police departments, fire departments, medical facilities, educational facilities, libraries, water providers and wastewater treatment facilities would be similar to those described for the Proposed Action with RFFAs. Adams County would also experience negligible negative effects.

Table 4.6.19-3 briefly summarizes the total effects experienced by the Gross Reservoir PIA and affected counties.

Table 4.6.19-3
Summary of Total Socioeconomic Impacts for Alternative 8a with RFFAs (2032)

	Gross Reservoir PIA	Boulder and Adams Counties, and Denver Metropolitan Area	Grand County
Economic Conditions	Negligible, positive	Negligible, positive	Negligible, positive and negative
Demographic Conditions	Negligible increase in population	Population growth is anticipated	Population growth is anticipated
Housing Conditions	Temporary minor to moderate impact to sales price	Housing availability and price linked to population growth	Housing availability and price linked to population growth
Fiscal Conditions	Negligible	Negligible	Negligible
Water Providers	Negligible	Benefits and costs for many providers as they develop projects to meet demands	Benefits and costs for many providers as they develop projects to meet demands
Wastewater Treatment Plants	Not applicable	Potential upgrades necessary	Potential upgrades necessary
Other Public Facilities and Services	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth

Source: Harvey Economics, 2012.

4.6.19.4 Alternative 10a with Reasonably Foreseeable Future Actions

4.6.19.4.1 Economic and Demographic Conditions

Gross Reservoir PIA

Total economic and demographic effects within the Gross Reservoir PIA would be similar to those described for the Proposed Action with RFFAs.

Denver Metropolitan Area and Boulder, Denver, and Adams Counties

Total economic and demographic effects within the Denver Metropolitan area and Boulder County would be similar to those described for the Proposed Action with RFFAs. In addition to the enlargement of Gross Reservoir, the development of the AWTP and conduits would create a larger number of jobs and have a slightly larger, positive, cumulative economic impacts in Denver and Adams counties.

Grand County

Total economic and demographic effects in Grand County would be the same as described for the Proposed Action with RFFAs, except that the total reduction in property value of parcels surrounding Grand Lake would amount to $1.34 million, compared with $1.1 million under the Proposed Action with RFFAs.

4.6.19.4.2 Fiscal Conditions

Impacts to operating revenues, operating expenditures and capital outlay expenditures for public agencies would be similar to those described for the Proposed Action with RFFAs.

4.6.19.4.3 Public Facilities and Services

Total impacts to public facilities and services in the Gross Reservoir PIA, Boulder County, Denver Metropolitan area and Grand County, including police departments, fire departments, medical facilities, educational facilities, libraries, water providers and wastewater treatment facilities would be similar to those described for the Proposed Action with RFFAs. Impacts in Denver and Adams counties would be negligible.

Table 4.6.19-4 briefly summarizes the total effects experienced by the Gross Reservoir PIA and affected counties.

Table 4.6.19-4
Summary of Total Socioeconomic Impacts for Alternative 10a with RFFAs (2032)

	Gross Reservoir PIA	Boulder, Adams and Denver Counties, and Denver Metropolitan Area	Grand County
Economic Conditions	Negligible, Positive	Negligible, positive	Negligible, positive and negative
Demographic Conditions	Negligible increase in population	Population growth is anticipated	Population growth is anticipated
Housing Conditions	Temporary minor to moderate impact to sales price	Housing availability and price linked to population growth	Housing availability and price linked to population growth
Fiscal Conditions	Negligible	Negligible	Negligible
Water Providers	Negligible	Benefits and costs for many providers as they develop projects to meet demands	Benefits and costs for many providers as they develop projects to meet demands
Wastewater Treatment Plants	Not applicable	Potential upgrades necessary	Potential upgrades necessary
Other Public Facilities and Services	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth

Source: Harvey Economics, 2012.

4.6.19.5 Alternative 13a with Reasonably Foreseeable Future Actions

4.6.19.5.1 Economic and Demographic Conditions

Gross Reservoir PIA

Total economic and demographic effects within the Gross Reservoir PIA would be the same as described for Alternative 8a with RFFAs.

Water Rights Acquisition Area PIA/ Weld County

The purchase of water rights and the subsequent dry-up of irrigated agricultural land in the Water Rights Acquisition Area PIA/ Weld County as part of the Proposed Action with RFFAs are not expected to add to the residential or commercial development of land in Adams or Weld counties; non-irrigated acreage is assumed to remain in agriculture. The cumulative economic loss from conversion of irrigated to dryland farming is considered minor. However, in combination with past and anticipated trends in the transfer of agricultural water to municipal and industrial use, the purchase of water rights as part of the Moffat Project would result in cumulative socioeconomic impacts to the Water Rights Acquisition Area PIA and Weld County.

None of the West Slope water-based actions would impact economic or demographic conditions in the Water Rights Acquisition Area PIA or Weld County; no construction activities or permanent employment would occur in this area and it is unlikely that any additional spending would occur within the PIA or Weld County. Several East Slope water-based projects would be located on the eastern side of the Denver Metropolitan area, potentially providing employment opportunities and increasing business activity in the PIA and Weld County. No changes in the demographic make-up of the PIA or Weld County populations are expected as a result of these projects.

Denver Metropolitan Area and Boulder, Weld, and Adams Counties

Total economic and demographic effects within the Denver Metropolitan area and Boulder County would be similar to those described for the Proposed Action with RFFAs. In addition to the enlargement of Gross Reservoir, the development of the South Platte River Facilities, AWTP and conduits would create a larger number of jobs and have a slightly larger, positive, cumulative economic impact. Weld and Adams counties would experience negligible, economic, and demographic effects.

Grand County

Total economic and demographic effects in Grand County would be the same as described for the Proposed Action with RFFAs, except that the total reduction in property value of parcels surrounding Grand Lake would amount to $1.34 million, compared with $1.1 million.

4.6.19.5.2 Fiscal Conditions

Impacts to operating revenues, operating expenditures and capital outlay expenditures for public agencies would be similar to those described for the Proposed Action with RFFAs.

4.6.19.5.3 Public Facilities and Services

Total impacts to public facilities and services in the Gross Reservoir PIA, Boulder County, Denver Metropolitan area and Grand County, including police departments, fire departments, medical facilities, educational facilities, libraries, water providers and wastewater treatment facilities would be similar to those described for the Proposed Action with RFFAs. Weld and Adams County public facilities and services would also experience negligible negative effects.

The general types of impacts applicable to services in other areas would also apply to the Water Rights Acquisition Area (WRAA), PIA, and Weld County. Many of the East Slope water-based RFFAs would affect flows in portions of the South Platte River; however, the water rights currently held by water providers in the PIA and in Weld County would be unaffected by these projects.

Table 4.6.19-5 briefly summarizes the total effects experienced by the Gross Reservoir PIA and affected counties.

Table 4.6.19-5
Summary of Total Socioeconomic Impacts for Alternative 13a with RFFAs (2032)

	Gross Reservoir PIA	WRAA PIA/Weld County	Boulder and Adams Counties, and Denver Metropolitan Area	Grand County
Economic Conditions	Negligible, positive	Negligible, negative	Negligible, positive	Negligible, positive and negative
Demographic Conditions	Negligible increase in population	Population growth is anticipated	Population growth is anticipated	Population growth is anticipated
Housing Conditions	Temporary minor to moderate impact to sales price	No impact	Housing availability and price linked to population growth	Housing availability and price linked to population growth
Fiscal Conditions	Negligible	Negligible	Negligible	Negligible
Water Providers	Negligible	Benefits and costs for many providers as they develop projects to meet demands	Benefits and costs for many providers as they develop projects to meet demands	Benefits and costs for many providers as they develop projects to meet demands
Wastewater Treatment Plants	Not applicable	Potential upgrades necessary	Potential upgrades necessary	Potential upgrades necessary
Other Public Facilities and Services	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth

Source: Harvey Economics, 2012.

4.6.19.6 No Action Alternative with Reasonably Foreseeable Future Actions

4.6.19.6.1 Economic and Demographic Conditions

Gross Reservoir PIA

As described for the Proposed Action with RFFAs, development of a limited number of large-lot single family homes is expected to occur on private lands within the PIA through

2032; this type of growth is consistent with historical trends for the area. However, under the No Action alternative, the Board of Water Commissioners (Denver Water) would rely more heavily on supplies in Gross Reservoir to meet demands, resulting in more frequent reservoir drawdowns which may potentially have the effect of reducing the desirability of the PIA as a place of residence. The more frequent drawdowns would have adverse visual and recreational impacts within the PIA. According to Section 5.17.6, "the area between the normal water elevation and the minimum drawdown level would remain barren of vegetation and would create unattractive visual contrasts for observers." Section 5.15.6 states that shoreline recreation, such as fishing, would be limited, as would car top boating, since access to the waterline would be more difficult. Additionally, the recreational experience for other users, such as hikers, would be diminished "due to the potentially unsightly nature of reduced water levels during peak use periods."

However, no other land-based RFFAs, and none of the East Slope or West Slope water-based RFFAs, would occur within the PIA. No economic stimulus or jobs would be created within the PIA and no changes in the demographic make-up of the population would be anticipated as the result of land- or water-based actions. Overall, under the No Action alternative, economic and demographic impacts within the PIA would solely be the result of Denver Water actions (i.e., mandatory restrictions and depletion of the Strategic Water Reserve), as described in Section 5.19.6.

Denver Metropolitan Area and Boulder, Jefferson, Adams, and Weld Counties

As described for the Proposed Action with RFFAs, population growth and associated development is projected to occur in cities, towns, and rural areas within the Denver Metropolitan area and along the Front Range, including Boulder, Jefferson, Adams, and Weld counties. Increases in population will result in construction of homes, expanded business activity and provide an overall economic stimulus. The collection of future water-based RFFAs would add to the economic stimulus by creating temporary jobs as part of construction activities and permanent jobs as part of on-going operations and maintenance activities; however, the Moffat Project would not add any additional jobs to these cumulative effects under the No Action Alternative. Denver Water customers would likely experience more frequent water restrictions, potentially adversely affecting business activity and quality of life, as described in Section 5.19.6. If other water-based RFFAs are not permitted or completed, customers of other utilities could face similar restrictions.

Grand County

Under the No Action Alternative, population growth and development would occur in Grand County as described for the Proposed Action with RFFAs, resulting in economic stimulus in various sectors.

As described in Section 3.19, the Grand County economy is heavily dependent on tourism and recreation, including water-based activities such as fishing, boating and skiing and land-based activities, such as hiking and mountain biking. Population growth, in combination with other West Slope water-based actions, would affect stream flows as described in Section 4.6.1 and in Appendix H for Full Use of the Existing System. Total flow changes resulting from the combined impact of all water-based RFFAs are unlikely to have a measurable effect on the Grand County's tourism and recreation based businesses or the overall economy. Total socioeconomic impacts to the Grand County tourist and recreation economy are expected to be negligible.

Housing prices in Grand County will be influenced by a number of factors as build-out is approached, including a variety of economic factors affecting real estate transactions, as well as the availability of properties and the demand for primary residences and second homes. Property values of homes surrounding Grand Lake are also influenced by the lake's water quality and clarity as discussed for the Proposed Action with RFFAs. Under the No Action Alternative, lake clarity would decrease by about 0.6 meter, resulting in a reduction in property value of about $1.34 million for landowners immediately surrounding the lake.

4.6.19.6.2 Fiscal Conditions

Impacts to operating revenues, operating expenditures and capital outlay expenditures for public agencies would be similar to those described for the Proposed Action with RFFAs. Land- and water-based RFFAs would result in a variety of economic activity along the Front Range and on the West Slope, generating sales tax revenue for a number of municipalities and other public entities. Future land-based actions, particularly population growth and development, would also result in additional property tax revenue as land is developed for homes and commercial businesses.[14] The location and timing of population growth would depend on a number of factors, including job growth, available land and economic conditions; tax revenue generated at any one location would likely be minimal. Denver Water's actions under the No Action Alternative would not affect the likelihood that land-based or other water-based RFFAs would occur.

Public entities may experience increased costs if additional or expanded services are required to meet the needs of the growing population along the Front Range and on the West Slope. Impacts to public services are discussed in Section 4.6.19.6.3. The costs associated with each water-based project would be borne by various entities and likely paid for via a number of mechanisms, including increased water rates, tap fees or other special charges applied to customers. It is unlikely that many outside agencies would experience increased operational costs or face additional capital investment as a result of water-based RFFAs; however, downstream water providers or wastewater treatment providers may be faced with additional costs related to reductions in flow or water quality issues. Water and wastewater treatment providers are discussed in more detail in Section 4.6.19.6.3.

4.6.19.6.3 Public Facilities and Services

Total socioeconomic impacts to public facilities and services in the Denver Metropolitan area and Grand County, including police departments, fire departments, medical facilities, educational facilities, libraries, water providers and wastewater treatment facilities would be similar to those described for the Proposed Action with RFFAs. Population growth and development would occur along the Front Range and in Grand County as described for the Proposed Action with RFFAs, along with associated increases in demands for services. It is likely that most water providers along the Front Range would enact additional water conservation measures in the future; Denver Water's mandatory water restrictions under the

[14] Some public entities may be exempt from paying property taxes; in those cases, any land purchased for project purposes would be permanently removed from property tax logs. Lost revenues are likely to be negligible relative to annual revenues collected.

No Action Alternative may overlap those conservation measures for some wholesale customers.

In Grand County, changes in stream flows would result in water shortages ranging from about 1 AF/yr up to 358 AF/yr for various water providers as build-out demands are approached. Grand County Water and Sanitation District and the Town of Fraser would face the largest shortages, 358 AF/yr and 247 AF/yr, respectively. Other providers would face shortages of between 1 AF/yr and 70 AF/yr. Grand County Water and Sanitation District staff indicates they would avoid potential future shortages through infrastructure investments, possibly including a new diversion from the Fraser River mainstem to enable use of their conditional Fraser River water rights, a pump station, and WTP (refer to Section 4.6.1). Other Grand County water providers facing shortages would eventually have to acquire additional water rights or find other solutions to close the gaps between available supplies and demands. These actions would likely require some amount of capital investment on the part of water providers, potentially resulting in rate and/ or fee increases for customers. None of the East Slope water-based RFFAs would appear to affect water supplies of Grand County water providers.

Grand County WWTPs are also expected to be impacted by the lower flows caused by population growth. The Winter Park and Fraser WWTPs are the most likely to be affected by changes in flows between Current Conditions (2006) and conditions under Full Use of the Existing System. As a result of changes in flows, the Fraser WWTP may be required to upgrade to a tertiary treatment process or make other infrastructure changes; this would involve a substantial capital investment on the part of the sanitation districts that use the plant, which would likely impact the local mill levy, as well as rates for customers. Grand County Water and Sanitation District's long range plans potentially include a new wastewater peaking plant, estimated to cost between $4 and $5 million. Other Grand County wastewater providers may also be required to upgrade, expand or construct new facilities to meet discharge permit requirements as a result of the combination of reasonably foreseeable future water-based actions, including the recently passed nutrient regulations. These activities would require capital investments, likely resulting in increases in customer rates.

Although population growth and reduced flows would eventually affect NPDES permits for these plants, a more imminent impact to these providers may be the Nutrient Management Control Regulation passed by the CDPHE, effective as of September 30, 2012.[15] This regulation limits the Total Phosphorus and Total Nitrogen discharged from WWTPs and other facilities and could mean upgrades or other facility changes for Grand County wastewater treatment providers.

Table 4.6.19-6 summarizes the total effects experienced by the Gross Reservoir PIA and affected counties under the No Action Alternative.

[15] Colorado Department of Public Health and Environment, Water Quality Control Division, Regulation #85.

Table 4.6.19-6
Summary of Total Socioeconomic Impacts
for the No Action Alternative with RFFAs (2032)

	Gross Reservoir PIA	Boulder, Jefferson, Adams, and Weld Counties, and Denver Metropolitan Area	Grand County
Economic Conditions	Negligible, positive	Negligible, positive	Negligible, positive and negative
Demographic Conditions	Negligible increase in population	Population growth is anticipated	Population growth is anticipated
Housing Conditions	Negligible increase in housing units	Housing availability and price linked to population growth	Housing availability and price linked to population growth
Fiscal Conditions	Negligible	Negligible	Negligible
Water Providers	Negligible	Benefits and costs for many providers as they develop projects to meet demands	Benefits and costs for many providers as they develop projects to meet demands
Wastewater Treatment Plants	Not applicable	Potential upgrades necessary	Potential upgrades necessary
Other Public Facilities and Services	Impacts generally linked to population growth	Impacts generally linked to population growth	Impacts generally linked to population growth

Source: Harvey Economics, 2012.

4.6.20 Hazardous Materials

The affected environment for hazardous materials is described for Current Conditions (2006) in Section 3.20. This cumulative impacts analysis evaluates the potential effect of each alternative in 2032, when an action alternative would be fully constructed and providing the full 18,000 acre-feet per year (AF/yr) of additional firm yield (i.e., Full Use of the Existing System with a [Moffat Collection System Project (Moffat Project or Project)] alternative) combined with other reasonably foreseeable future actions (RFFAs). The potential total effects from hazardous materials are evaluated against Current Conditions (2006).

4.6.20.1 Proposed Action (Alternative 1a) with Reasonably Foreseeable Future Actions

Impacts from hazardous materials may result from construction-related activities in areas where contaminated soil or groundwater occur. No direct or indirect impacts associated with hazardous material sites were identified within the Gross Reservoir study area, therefore no cumulative impacts related to hazardous materials would result from the Moffat Project with RFFAs.

Although various hazardous materials would be used during construction at Gross Reservoir and other planned development in area, their storage, use, and disposal would be subject to local, State, and Federal regulations. A Materials Handling Plan would be developed for each of these projects to properly handle and dispose of contaminated materials. Mitigation of impacts from hazardous materials would consist of modifying construction activities to avoid conflict with subsurface contamination. If contaminated soils or groundwater are identified during construction activities they would be segregated and managed in accordance with appropriate regulations. If any property is to be acquired, a site-specific investigation, such as a Phase I or Phase II environmental site assessment, of that property should be performed. Overall, cumulative impacts of hazardous materials in the Project area are considered minor.

4.6.20.2 Alternative 1c with Reasonably Foreseeable Future Actions

The total environmental effects from hazardous materials at Gross Reservoir for Alternative 1c would be that same as those described for the Proposed Action with RFFAs.

No recognized hazardous material sites were identified from the database search within the Leyden Gulch Reservoir site. Rocky Flats and two landfills that are adjacent to the Leyden Gulch Reservoir site, however, were identified. Unknown or low impacts from hazardous materials are associated with these landfills. Therefore, cumulative impacts related to hazardous materials are not anticipated from the Moffat Project. Planned development and transportation improvement projects in the area would be required to implement a Materials Handling Plan to properly handle and dispose of contaminated materials. Appropriate mitigation of impacts from hazardous materials during construction would also be required. If any property is to be acquired, a site-specific investigation, such as a Phase I or Phase II environmental site assessment, of that property should be performed. Overall, cumulative impacts of hazardous materials in the Leyden Gulch Reservoir site are considered minor.

4.6.20.3 Alternative 8a with Reasonably Foreseeable Future Actions

The total environmental effects from hazardous materials at Gross Reservoir for Alternative 8a would be that same as those described for the Proposed Action with RFFAs.

Several sites with a high potential for an environmental release were identified within and adjacent to Worthing and South Tower pits. No impacts associated with hazardous material sites were identified near the North Tower Pit. Moderate potential impact from hazardous materials associated with two aboveground storage tanks (no violations recorded) were identified near Challenger Pit. For Alternative 8a, it was assumed that when the Board of Water Commissioners (Denver Water) acquires the gravel pits they would be completely mined and reclaimed for use as an empty water storage facility. Construction activities that would be associated with Conduit O, the gravel pit pipelines, and the Advanced Water Treatment Plant would implement appropriate Material Handling Plans and mitigation measures if hazardous materials are encountered. Overall, cumulative impacts from hazardous materials under Alternative 8a are expected to be negligible to minor, particularly in comparison with regional emissions associated with existing and projected development in Adams County.

4.6.20.4 Alternative 10a with Reasonably Foreseeable Future Actions

The total environmental effects from hazardous materials at Gross Reservoir for Alternative 10a would be that same as those described for the Alternative 8a.

Conduit M, Denver Basin Aquifer distribution pipeline and associated treatment facilities would be constructed in previously disturbed industrial and urban areas including roads and other right-of-ways. Thus, these components of Alternative 10a were not evaluated for hazardous material releases for the Moffat Project with RFFAs due to the expected high number of hazardous waste sites associated with the urban location of large portions of these components. If Alternative 10a is selected, a detailed hazardous materials analysis would be conducted so that appropriate mitigation measures could be identified and implemented prior to construction activity. Thus, cumulative impacts from hazardous materials under Alternative 10a are expected to be negligible to minor, particularly in comparison with regional emissions associated with existing and projected development in Denver County.

4.6.20.5 Alternative 13a with Reasonably Foreseeable Future Actions

The total environmental effects from hazardous materials at Gross Reservoir for Alternative 13a would be that same as those described for the Proposed Action with RFFAs.

The total environmental effects to hazardous resources for the South Platte River Facilities and Conduit O are the same as those described above for Alternative 8a.

4.6.20.6 No Action Alternative with Reasonably Foreseeable Future Actions

No ground-disturbing activities would result from the No Action Alternative. Therefore, no cumulative impacts to hazardous materials are anticipated.